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# ARTIFICE AND DESIGN

*Art and Technology in Human Experience*

BARRY ALLEN

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For
Gilbert and Adria Allen
Loving and generous parents

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B.A.

# ARTIFICE AND DESIGN

# INTRODUCTION

## *Art and Technology in Human Experience*

Only those who already know the value of the useless can be talked to about the useful.

Zhuangzi

There are many books about art, many about technology, but few about art *and* technology—about their affinity and the relationship of both together to human experience.[1] It is this relationship that is my topic here. I develop philosophical concepts of art, artifact, knowledge, technology, and tool, which I use to explore parallel questions about artistry in technology and technics in art. The result is a work of interdisciplinary philosophical research, with concepts and arguments drawn from evolutionary biology, cognitive psychology, science studies, aesthetics, and the history, philosophy, and anthropology of art and technology.

Setting my topics in the broad context of human existence, which I understand from an evolutionary point of view, my book is a contribution to what may be called philosophical anthropology, an expression I use in remembrance of Protagoras, the fifth-century B.C.E. Greek philosopher, and his great saying that *anthropos* (human being) is the measure of all things. I think he's saying that what measure there is, what value, proportion, ratio, or significance, comes from us, from our life and practice. We have no alternative to a human perception. We see as we are—we can't look around our own corner. Protagoras acknowledges the unavoidable humanity of understanding (even truth) and embraces it, mak-

ing *anthropos* the alpha and omega of philosophical inquiry, the lens under which thoughts focus to a philosophical point.[2]

That will be my philosophical orientation too. In chapter 1, "The Human," I develop the empirical, scientific context for an anthropological philosophy of art and technology. I select my topics, which include human evolution, perception, cognition, and language, for relevance to the argument of later chapters. Consequently, I have a good deal to say about hands but nothing about kinship, a lot about perception and language and (almost) nothing about violence or sex.

Chapter 2 is about the *Technical,* a concept I apply to any human group or community, which must make use of some tools and practice some techniques, constituting what I call their technics or technical culture. I don't begin my account of the Technical there, however. I begin with the effects of technics, which are *artifacts.* Though it should be fundamental to philosophy, the concept of artifact has attracted little attention, and ideas have made no progress since Aristotle. One task of chapter 2 is to interrogate the philosophers (and latterly the social scientists) on their ideas about artifacts, artifice, and tools. Exposing their assumptions makes the need acute for a new approach to concepts in the philosophy of technology. What is a tool? a technique? a machine? technology? What makes action technical?

There is more to technology than tools, but if you don't understand tools, you can't make sense of technology. The "well-known fact" that many animal species, especially chimpanzees, make and use tools is a persistent stumbling block. It takes a peculiar blindness to our own tools to see anything like their use in other species. Let's say a chimpanzee takes up a stick, manipulates it, and makes it facilitate eating ants or termites; or slams a rock on a nut, exposing the morsel inside. If it seems obvious to you that these actions are tool use, I'll be urging you to think again. When we examine *our* tools as carefully as specialists do the so-called tools of chimpanzees it is apparent that their rocks and sticks are insignificant and obviously misleading analogies.

Since we have to call it something, and it isn't a tool, I call what the chimpanzee uses a proto-tool. It is a found object manipulated into a facilitating posture, like tearing a twig from a tree and making it facilitate eating termites. Tools acquire their instrumental potency in a completely different way. The use of tools may, of course, require manipulation, but what makes tools facilitating is not merely how a user manipulates them. They are *designed and made,* usually by others, to facilitate action. If in the wilderness I pick up a stone and *use it as a hammer,* I am not using a tool nobody made. I am using a stone as if it were a tool, which it is not. It is a proto-tool—a conveniently nonce object manipulated into facilitation. A tool is not so fortuitous or accidentally expedient. To use a tool is to use something tools have made for use. Tools are artifacts from the beginning,

even before they are picked up and used—artifacts made by others, made to facilitate, circulating in a community like commodities or gifts.

The most important thing about tools, and what distinguishes them from the proto-tools of chimpanzees, is that they are already artifacts when we pick them up, already products of others' artifice with other tools, reciprocally linked to other tools and other people in an economy of actions, agents, and artifacts. Economy is the right word, and not a metaphor. There is nothing intrinsically monetary about an economy—money and commodities are merely conspicuous examples of economic entities. So are the words of a language, as are kin and gifts. Economic entities (dollars, nouns, uncles) exist solely through reciprocal, mutually conditioned and conditioning relations to others of their kind. Tools are made with tools, as words are defined by words, as kin beget kin, as one gift calls for another. There is nothing analogous to this intersubjective intentionality in the so-called use of tools by chimpanzees. We shall see why this difference, with its evolutionary genealogy, cognitive presuppositions, and social consequences, makes all the difference to human life. It makes our existence "technical" in a way without parallel in contemporary species.

*The Aesthetic* (chapter 3) is an anthropological category parallel to the Technical. The subject of aesthetics as I understand it is the whole felt, perceptual appeal of artifice. Others address us with speech, but they are not all that appeal and elicit a response. Things do, too, especially artifacts, or things that look like artifacts—that look like they are designed or purposely made. So great is the presence of speech that, being addressed I cannot *not* reply, as even silence becomes an answer. The appeal of artifacts (when they are appealing) is not like that. They do not speak—they *look* or *sound.* Their compelling perceptibility (when they have it) motivates attention, lingering, and memory. They do all of that (if they do) just by how they look or sound, without discursive, linguistically mediated reasoning about what they are, or mean, or might be good for.

Artful artifice anticipates perception, being designed to appeal to the senses, to delight, fascinate, charm, or sometimes mystify or overwhelm. The usual compliment for such work is *beautiful.* An aesthetic response is not invariably delightful, however. Ugliness, no less an aesthetic response than the feeling of beauty, is the experience when perception's felt nimbus has an opposite character; when it is disagreeable, even painful, not for personal reasons, or reasons of any kind, but just as perception, just the look or sound of it. Beautiful means more than *I like it.* It means perception that is liked because of how it's been anticipated by design (I am not forgetting natural beauty). Similarly, *ugly* is not personal dislike. The ugly is not liked because it repels liking, repulsing the contemplation its egregious presence solicits.

I distinguish the Technical (technics or technical culture) from Technology, which is the topic of chapter 4. The distinction is not usual among scholars, who

tend to equate tools and technology. In my argument, technology is a special sort of technical culture, a specific way in which a socio-technical economy of tools and techniques can be organized. A technological economy emerges when tools and other devices come to be designed as much for each other as for the people who interact with them. The machine-machine interface becomes as important (socially, technically, economically) as the human relation, the perceptual or aesthetic interface. The transformation of societies largely innocent of such economies into ones where it is the norm is a historical event, something that happened in first one and then many societies, beginning with industrialization in Britain in the eighteenth century.

Establishing a philosophical concept of technology is one task of chapter 4. A second is to tease out the relationship between aesthetics and technical design. Can aesthetics really matter to engineering? What about instrumental rationality and functional logic? I develop several examples from the engineering of bridges. As familiar and widely appreciated works of modern technology, bridges are a good place to study the relationship between the Aesthetic and the Technical. An idea I expect to take away from my look at bridges is that fully engaged technical design is at once aesthetic and structural. In the best work (the best design, the most well made), the look and feel of a device (its aesthetic, perceptual interface) is as important a part of the design problem as its mechanism (the interface of parts and systems). Devices don't work, or don't work as well as they could, unless both moments, aesthetic and technical, are taken into account. We have no idea how to make something that is merely efficient, a rational instrument blindly indifferent to how it appears. No engineer can design such a thing and none has ever been built.

Chapters 2 and 4 set out the basic concepts of a philosophy of technology. Chapters 3 and 5 develop a parallel argument for aesthetics and the philosophy of art. Chapter 3, "The Aesthetic," is not about art at all. It concerns the roots—evolutionary, perceptual, and cognitive—of the responsiveness to artifice variously cultivated in the world's arts traditions. It's one thing to be able to feel the beauty of perception, something else to contrive this experience by technical means. *That's* art, the art of art, and it takes more than feelings. It takes skilled hands and stylistic traditions. It takes practice and technique. Naive aesthetic response requires no more than our evolved capacity for preferential perception, but to *make* a thing aesthetically appealing takes artifice, design, and cultivation, being a problem at once of aesthetic sensitivity and technical accomplishment, which is what art is.

*What art is?* Abstract definitions of art are seldom helpful. Many have been proposed, but they are usually tendentious redefinitions, polemically contrived to favor one over another movement or epoch in art's complex, pluralistic history. We'll see why art must resist abstract definition. It's because art is not a pure con-

cept or formal category. It has no essence or nature. Art is not even necessarily beautiful or aesthetically valuable in any way. Works of art can be indifferent or hostile to the perception they solicit. The twentieth century saw many such works, epitomized by Marcel Duchamp's *Fountain* (1917)—a urinal, purchased at a hardware store and offered "ready-made" for exhibition. I discuss this phenomenon of anti-aesthetic art in chapter 5.

A constructive way to avoid the essentialism of formal definition is to compare art to an evolving biological genus. I stress that the comparison is merely an analogy, not an "evolutionary" (or "biological") theory of art. A genus has no essence. Its evolution is not a teleological progress to ever higher species. Its history is just so much variety and opportunistic contingency. So too in the genealogy of art, from the present all the way back to Paleolithic cave painting and carving thirty thousand years ago, which is near the zero-point of aesthetic design and the beginning of art. No single narrative sweeps everything ever done anywhere into an edifying tale of progress toward Ideal Beauty. But wherever artful artifice is practiced, wherever artifacts are designed to anticipate their perception, to appeal, charm, seduce, or overwhelm, there are technical practices, traditions of design, cultivation, pedagogy, and a vocabulary of appreciation. A work of art is the artifact of such a history, having such ancestors and historical contexts of production.

Despite my reservations about essentialism, this approach does support one generalization that is as close as I come to a definition of art. A characteristic quality that runs throughout art's history worldwide, and which allows us to see that there is a history here—a genealogy of descent with modification—is technical concern with the anticipation of an artifact's perception. Something—anything—becomes art (artful or artistically motivated) when there is an evident concern on the maker's part for the effect of artifice on its own perception. That means an evident concern for how a made thing looks or sounds, perhaps even how it tastes, smells, or feels. In short, concern for what it is like to perceive it. That is not necessarily a concern to please, though the result often does please. What matters is that the experience of perception is deliberately, artfully anticipated in the artifice of an artifact.

This anticipation of perception makes art a *technical* accomplishment because success requires technical concern with the relationship between how a thing is put together and the perceptual (rather than mechanical, economic, or pedagogic) result. Not that perceptual and mechanical (or economic and pedagogic) can be sharply distinguished. Art, like other products of human intentionality, is overdetermined. Nevertheless, where there is evident concern for what it is like to perceive an artifact, there is something artful, artistic, art-like about the result. And where this concern enters decisively into artifice, the result is at once a technical

and an aesthetic accomplishment. Hence the inevitable, or nearly inevitable, reciprocity of art and technics. The exceptions, where they exist, are primarily in some twentieth-century art, where indifference to artifice—to technical work—is cultivated as a radical anti-ideal. Yet even here, as I shall show in chapter 5, the characteristic preoccupation with perceptual effect cannot be eliminated without descent into artistic nihilism.

We can see that technology matters to the future as never before. But don't we also tend to think that technology is too rational and scientific to be detained by aesthetics or the taste for beauty? And anyway, *which* aesthetics, *whose* beauty? *De gustibus non disputandum est,* as scholastics used to say. There's no disputing taste.

I wish it were that simple. The idea that Art is something subjective or an arbitrary social representation, while Technology is governed by a functional logic of instrumental rationality, is a mistake. The dichotomy distinguishes and separates what is indistinct and really mixed up in reality. There's nothing "pure" about technology. It is not a system with its own autonomous rationality.[3] To talk about real-world technology is always to talk about a people, an economy, a history, a tradition of artifice and design. That makes tools in the widest sense—including all our implements, utilities, devices, and artifactual facilitations—more social than a mere physical thing and sometimes no less obstinate than a person. These artifacts are other—not people; yet they are also an *Other,* a partner, a collaborator enrolled in a plan of action—the *other* Other.

We'll see why there never could be a "one best way" to make anything technically complex. If all we had to rely on in technology were the calculations of means-ends rationality we would still be waiting for the first stone tool. There is a gap, more an abyss, between rationality about means or function and a finished artifact. What finishes the work, conditioning its form, shape, parts, and design, is historical socio-technical practice, including the concerted operation of skill, technique, and craft—everything Greeks called *techne* and Romans *ars,* centuries before modern rationalism began to insist on the distinction between art and technology.

Finally, I will be suggesting that we pay more attention to the aesthetics of technology; that a civilization as ineluctably technological as ours should be aesthetically more demanding of technology. There are two reasons, or two sides of one basic reason, why I say that. First, because with qualifications I'll discuss, aesthetic rightness is a component of technical rightness, whether in art or technology. Continuing that thought a step further, it is only when technology is practiced as art—when it is free to be practiced as art—that it can do its best work.

Exactly what I mean by "the best work" will have to be explained, and I do so in chapter 4, primarily through examples, which I hope are more convincing than

an abstract definition. If I am right, however, and the freedom to be art does belong to the conditions of the best technology, that's worth heeding. Our own artifacts, especially technological artifacts, are now the leading source of ecological uncertainty in the world. To disengage from technology is not an option—we'll see why. The alternative is a more profoundly technological technology. That doesn't mean "a technological fix for the problems of technology." There is ultimately no distinction between a technological solution and a social, political, even aesthetic solution, because what "works" is conditioned as much by available or invented technology as by the political, economic, historical, and aesthetic contexts that ultimately define any "technological" problem, as well as the scope of acceptable solutions.

This point is acknowledged by specialists in the history and sociology of technology, though not more widely appreciated. People tend to believe that what is technically possible is determined by a physics of nature indifferent to politics and history, which are viewed as mere obstacles, however justified, to what pure technical thought and ingenuity might accomplish. Such objectivity, such inhuman purity, is not just a myth, which might be harmless. By isolating our understanding of technical change from the all-too-human factors that actually condition what happens—or does not happen—in science and technology, belief in this inhuman objectivity is an ideological impediment to the free deliberation humane science and technology require.[4]

What I have in mind as a more profoundly technological technology is a topic reserved for my conclusion, where I argue that such a technology would be a more artful one, with technological design enjoying greater freedom to be practiced as art, overcoming economic and administrative opposition to the widest possible consideration of a work's place in humanity's built environment. Sustainable solutions to problems of technological ecology now and to come require engineering design to liberate itself, ethically, professionally, and politically, from the destructive economics of the short term (where "short" is anything less than a thousand years). It is challenged to grasp technical problems as ultimately problems of art, and more consistently, systematically, and professionally take up art's concern for the perceptual interface of artifice.

Art is born from care about the look and feel of things people make. Its practice cultivates such care, and the more art cares for, the more humane the built world becomes. Art works to make works appealing, and it works, at least potentially, on every point of our perceptual interface with artifice, everywhere works touch us or make a difference to our experience. There may be no better way to make the built world humane than by striving to make it beautiful. When we sequester art and technology into incommensurable categories, like the instrumental rationality of engineering and the arbitrary sentiment of aesthetic preference,

we divide ourselves against ourselves, casting up self-made obstacles to the ingenious synergy of artifice and design.

That, then, is why I have written a book not about art and also about technology (or vice versa), but about their relationship. That relationship is mediated by the human form of life. It is because we are as we are—because of our genealogy, biological and historical—that my topics belong together. Before I talk about art and technology, therefore, I must first talk about human beings.

# 1. THE HUMAN

The study of what it is to be human has no boundaries and is as much about writing the future as it is about excavating the past.

Jonathan Kingdon, *Lowly Origin*

Now that liberation from the shackles of theologically underpinned oppression is less of an issue, at least in the West, overlooking the exceptional character of humans is simply boring.

Raymond Tallis, *The Hand*

Part of what it is to be "philosophical" about a subject is to take a long view of it. The view from eternity, seeing the world as a fixed and changeless whole, is a traditional ideal of Western theory. I prefer a timescale more down-to-earth, one that is secular, evolutionary, and unrepentantly anthropocentric: the time since the appearance of bipedal hominids, about 4.5 million years ago; since the first species of the *Homo* genus, about 2.5 million years ago; and since the consolidation of the modern *sapiens* mutation, about 160,000 years ago. My scientific perspective is that of Darwinian evolution, though readers will find my argument unlike current views in sociobiology and evolutionary psychology, which represent human beings as assemblages of evolutionary "algorithms," naturally selected instincts inherited from evolutionary ancestors adapted to life in prehistoric Africa.[1]

Darwin was already aware of the explanatory limitations of adaptation by natural selection. He lavishly overdetermines most evolutions, supplementing natural selection with several other causes, including use inheritance and what he calls correlated variation, renamed exaptation (more popularly *spandrels*) by Steven Jay Gould. Darwin never equated the process of evolution with adaptation or with the effects of natural selection, which he knew to be a limited cause of evolution. He says we should take care not to attribute "too much to the action

of natural selection or the survival of the fittest," or overlook "the existence of structures, which, as far as we can at present judge, are neither beneficial nor injurious."[2] Traits that may look like adaptations can be contingent by-products of other (possibly naturally selected) changes. These are Gould's "exapted" spandrels—structures and functions not ad-apted to a way of life by natural selection, but opportunistically ex-apted, taken over after the fact.[3]

Spandrels seem likely in human evolution, especially in the evolution of the brain. The more complex an organ becomes, the more interconnected its parts, hence the more difficult it becomes to change anything without unpredictable consequences. Sometimes the consequences are fatal. Other times they are neutral. Sometimes they afford a new opportunity from which an organism is capable of benefiting. Since the hominid brain is the most complex system in the known universe, we should expect the major transitions of neural evolution to throw up important spandrels. My argument in *Knowledge and Civilization* is that knowledge is one of them. Now I'm adding art and technology.

## Evolution

One implication of an evolutionary view is that there are no simple origins. Nothing evolved ever simply starts, ex nihilo. The ultimate origin of life is no part of the theory of evolution. Darwin insisted on that. Every new species redescribes the extinction of others in the survivors' terms. Abolishing ultimate origins concentrates evolutionary questions on genealogy, or relative origins. An evolved species is an entirely relative thing, humans included. What it is depends on what it is related to.

Who are the human relatives? That depends how far back you want to go. Relatives are relative things. We are mammals, and all mammals have a common ancestor, *Hadrocodium,* a diminutive shrew-like creature 195 million years ago. Some of our mitochondria, which are usually restricted to the cytoplasm between our cells' outer membrane and the DNA-containing nucleus, have worked their way into the nuclear DNA. Since the mitochondria themselves derive from a symbiotic relationship between what were once independent organisms, the ancestral mitochondria being formerly free-living bacteria, stretches of our genome are bacterial in origin. We are kin to *E. coli* and its ilk, which takes human relatives back to the emergence of bacterial life more than three billion years ago.[4]

Human beings today are a species, *Homo sapiens.*[5] We belong to a genus, *Homo,* of which there are eight, ten, or more other species, all extinct.[6] The presently oldest *Homo* of secure date is from Gona, Ethiopia, 2.6 million years ago. The same site holds the oldest evidence of stone tools.[7] The *Homo* genus be-

longs to a biological order, primates, which includes all the apes and monkeys. Primates have existed for about fifty million years. They were among the first mammals to take advantage of the cataclysmic extinction of dinosaurs. The first primates were small nocturnal insect-eaters. Apes emerged in the Miocene 22 million years ago, when formerly nocturnal primates invaded the day. Hominids—apes on two legs—appear about 4.5 million years ago, and include at least eight genera (*Orrorin, Kenyanthropus, Sahelanthropus, Ardipithicus, Praeanthropus, Australopithecus, Paranthropus, Homo*), most with several known species, all extinct—apart from us.[8]

It is imprecise though convenient to define hominids as bipedal primates.[9] Bipedalism is usually thought to begin as a feeding strategy, which is how a bipedal stance is used by baboons living in an East African savannah believed to resemble the environment of human evolution. We'll see, however, that savannah is not the ecological context of evolution in the *Homo* genus. I'm drawn to the alternative argument of African zoologist Jonathan Kingdon, who thinks bipedalism emerged (via squat-feeding) in the river valleys of East African forests, where resources were rich and secure. The move to open woodland (savannah) comes after bipedalism and is not the scene of its evolution.

Kingdon thinks early generations of a newly bipedal primate were led from the river basins out into woodland in pursuit of a strategy he calls niche-stealing. This is not the benign or creative process of enlarging niches. It is taking them away from other species. On Kingdon's account, that's what drew us onto the savannah. A species with a well-defined forest niche evolved into one that collects niches (among them, savannah), taking advantage of bipedal locomotion, hands, communication, and tools to remove other species from coveted resources. Eventually, removing obstacles to resources ("development") became a leading strategy of human economy. We married this prehistoric strategy to modern technology and economy, even as the global scale of the destruction of habitats makes it an increasingly dangerous way to live. We are now in the unenviable position of depending for survival on successfully changing the very behaviors that account for our success as a species.[10]

Our species, *Homo sapiens,* or what specialists call "anatomically modern humans," first appears about 160,000 years ago in southern Africa.[11] There is no evidence of our kind outside of Africa until about 60,000 years ago. Our first 100,000 years were spent as a gradually expanding African group with probably only thin cultural differences. Modern *sapiens* is the last, late birth of a Pleistocene African genus that had been evolving, especially neurologically and through artifacts, for 2 million years. The new species emerges in a milieu already saturated with artifacts, including (by that time) Middle Stone Age tools; the use of fire; clothing; rituals; and probably language in some form. Such was our inheritance from earlier

species. That makes us something of an artifact ourselves. We are effects of earlier species' artifacts on an evolutionary time scale, and the effects of artifacts are artifacts, as I shall explain in the next chapter.

The modern human diaspora out of Africa began about 60,000 years ago. Partly we followed the trail of earlier hominids. *Erectus* had already taken a coastal path into China and Indonesia; Neanderthal, possibly the first hominid to evolve outside of Africa, had colonized Europe and the Middle East. The modern *sapiens* diaspora seems to roll steadily eastward out of Africa, favoring coastal routes. Here are places and dates for the earliest modern human sites outside Africa, running west to east:

- Middle East, 45,000 B.P.
- Europe, 40,000 B.P.
- Sri Lanka, 31,000 B.P.
- Thailand, 37,000 B.P.
- New Guinea, 40,000 B.P.
- Americas, 15–20,000 B.P.

There is one difficulty for this picture of a rolling exodus. The very oldest non-African site of modern human habitation is in Australia (Mungo Lake). Current thinking dates the site to 60,000 B.P., making it 15,000 years older than the oldest site on the list, and half a world away. It is worth noting, too, that a land journey to Australia has never been possible. The first Australians already had boats.[12]

The human diaspora can be traced in detail by the distribution of genetic markers in contemporary populations. This research has shown that the first modern humans in Europe, the Cro-Magnon people, did not come from Africa via the Middle East but from central Asia. Most European men have a male ancestor in central Asia within the last 35,000 years, while an analysis of twelve thousand men in central Asia found 100 percent with ancestors in Africa within 50,000 years. All the human genetic variety in the world today was already in Africa 60,000 years ago. The so-called racial features of modern human groups did not then exist. They are relatively recent, from about 30,000 years ago. It is thought they result from a fragmentation of groups at the onset of last ice age. Older fossil humans, whether African, Asian, or European, are apparently very similar, and don't show the "racial" distinctions we imagine in these populations today.[13]

Everyone (it seems) knows about the "small" genetic difference between humans and chimpanzees—we are 98 percent genetically identical.[14] This degree of genetic identity is apparently very significant, though it is seldom explained why. Someone has called it the most overexposed factoid in modern science, and I agree.[15] Overexposed and not exactly factual—a factoid is not a fact; people just think it is. Since we don't look like chimpanzees and don't behave like them, one

has to wonder what it means to say that we are 98 percent genetically identical with them.

Very little as it turns out. The structure of DNA, with four elements to any sequence, makes it impossible for randomly chosen bits of DNA to differ by more than 75 percent. Literally any two organisms (a rose and a rhino) cannot fail to be more than 25 percent genetically identical, whatever that means! Since 25 percent is actually the zero-point, these "genetic identity" comparisons overestimate similarity at the low end and underestimate difference at the high end, where we and the chimps are. Also, most of the research looks only at selected parts of each genome. According to an author of one of the first studies, if the comparison is extended to the whole genome, there are some 32 million substitution differences (about 6.5 percent) between humans and chimpanzees.[16]

Is that still a small difference? Bear in mind that the effect of any one gene depends on others which may be distributed anywhere over the genome. One and the same gene can have quite different effects depending on what other genes are present or active. "For two genes to be really the same," explains geneticist George C. Williams, "every one of the thousands of base pairs has to be the same. If proportions of such exactly similar genes are estimated, it may be found that a quarter to a third of the genes may differ in human and ape cells."[17] Also, something depends on exactly which 2 percent of our genes are different. With appropriate distribution, a 2 percent difference can alter the effects of *every single human gene*.[18] Perhaps that's why genetic similarity predicts nothing about any other similarity with apes. Knowing the number of identical genetic base pairs in humans and chimpanzees tells us nothing about how these identical genes interact with the rest of the genome, the rest of the cell, or the rest of the world. Yet it is precisely that (the part we do *not* know) which distinguishes chimpanzees and human beings. It is not genes, nor genes primarily, nor even genes-plus-environment that make organisms what they are. An organism is an evolved developmental process in which gene action is no more than a complicated part of a complicated story.

What genes do or can do depends very much on the larger structures—from cells and organs to organisms and ecologies—in which they are situated. Contrary to what is often said or presupposed, genetic information does not contain the instructions to build an organism. The same stretch of DNA can play different roles at different times and places in the same cell, and there is seldom if ever a direct relation between a DNA sequence and a specific function in development. At least as much information necessary for development lies outside the genes (in cells, organs, organisms, ecologies), and more is transmitted to offspring than the recombined parental DNA. No one factor bears the fundamental form that requires all others for expression, and without these further levels of information and causation, genes are impotent.[19]

## Hands

> The hand must seize a thing before one knows it perfectly.
>
> Yan Yuan

In his novel *Blindness,* Portuguese author José Saramago imagines the catastrophe of a world suddenly struck blind.[20] In a matter of weeks, everyone everywhere loses their sight. One alone is spared, a solitary witness through whose eyes we watch the descent into chaos. Try and imagine a different scenario. We retain our vision but lose our hands, or even just our fingers and thumbs. Imagine waking up to surgical stumps at the end of your palms. How do you dress, eat, drive, telephone? Struggling with the door, and inadequately clothed, you stumble outside to stare at neighbors equally stumped.

I have a feeling like suffocation, like being buried alive, when I linger on this imaginary scenario. What could we do, how could we cope, with absolutely no one anywhere able to use their fingers? We could invent nothing. No clever engineers could contrive robots or prosthetic hands, for they have no hands with which to contrive anything. Even if we already had robots they would have to take care of each other, because the first time one broke down we would be like infants reduced to impotent thrashing. Within days many technological systems would cease to operate, and in time all of them would. There would be no further invention and rapidly diminishing use of what has already been invented, practically all of which ultimately presupposes hands.

Hands condition artifice and design no less profoundly than eye and brain. So it seems appropriate to get acquainted with these perhaps over-familiar allies.[21] To begin with anatomy, our hand is, of course, an evolution. The basic plan of the primate hand is that of a pentadactyl tetrapod, like a newt or crocodile. Primate hands evolved from the five-rayed forepaw of early vertebrates, retaining the primitive pattern and usually five digits. The earliest primate of modern aspect, from about 50 million years ago, is said to have resembled a squirrel monkey, and had nails instead of claws. The australopithecine remains at Hadar, which are more than 3 million years old, show hands and feet both shaped for climbing, with thumb and finger articulation denoting arboreal activity. The hands of *H. habilis* (Olduvai, 1.8 million years ago) are apparently a mosaic of primitive and derived—hands that might make a tool, but retained a penchant for refuge in trees.

Specialists report a wide range of hand morphologies among primates. Even the most characteristic features (like an opposable thumb) are missing in some genera and families, for instance, the nonopposable claw hand of marmosets and tamarins. Apes took their own way, evolving anatomical and muscular special-

izations for knuckle-walking and brachiation.[22] Because these uses place high mechanical demands on arms and hands, they keep the hand wedded to the arm, where it is more important to stabilize a lumbering body than to exercise precise manipulation. Hominid bipedalism released hands from use in locomotion. This happened early in evolution, when our ancestors were still relatively light (early australopithecines are thought to have weighed about 30 kilograms). A hand liberated from propulsion was apparently able to cultivate the unspecialized plan of tree-dwelling prosimians, light and nimble rather than robust and reinforced for locomotion.

It takes neurology to make something special of the unspecialized affordances hand anatomy offers. "The hand itself is derived from yeoman stock," writes philosophical anatomist John Napier, "but the factor that places it among the nobles is, as it were, its connections."[23] Most of these connections (neurons) are for motor control. The distinction of our hand among primates is our range of voluntary movement, especially independent (so-called fractionated) finger movement. Our hand has twenty-eight degrees of mechanical freedom, meaning independent vectors of movement. More than 20 percent of this flexibility is in the thumb alone. An opposable thumb is, of course, the epitome of manual dexterity.[24] To oppose the tip of the thumb to the tip of the index finger, with full pulp contact between the two digits, is our most precise manual achievement. Co-opted by gesture it denotes all things right. With precision we gain an almost unlimited potential for fine pressure adjustments and corrections of direction. Yet this flexibility didn't come quick and easy. First, our forebears had to replace ancestral claws with fingernails. Full pad-to-pad contact between the thumb and each finger also required the evolution of a revolving saddle-joint that monopolizes almost 40 percent of the hand's muscles (24 percent in apes).

Skin characteristics and subcutaneous fat on finger pads and palms contribute to stable gripping and the generation of force. Yet gripping is not the hand's single service. It is also a sensory device, a source of input, and an instrument of communication. The fingers and palm are richly supplied with sensory endings. People everywhere use the same repertory of manual exploratory procedures: lateral motion and contour following (stroke it); pressure (push it); static contact (touch it); unsupported holding; and enclosing. From these procedures hands discover surface properties like texture, hardness, and temperature, and structural properties like shape, volume, and weight. Sensory and motor functions are also intertwined. We spontaneously manipulate things in order to perceive them, hands effortlessly switching from sensing to manipulating organs.

A human grip is so flexible that it necessarily becomes a matter of purpose, choice, and strategy precisely *how* anything is held or manipulated.[25] Every grip is customized; a nonstandard grip is standard. We unconsciously begin to form a

grip as we launch our hand toward an object. The contours of the prefigured grip take into account not just the object's shape but also the approach angle, the intended manipulation, and the circumstances of action. An intriguing experiment reveals the hand's cognitive agency. An apparatus made it impossible for subjects to visually judge the size of two disks. Estimates were consistently wrong. But when asked to reach for the disks, with experimenters measuring the preformed grip, the hand's configuration accurately matched the actual size of the target. The hands were making their own correct judgment of size, using the eyes in a way that bypasses conscious vision.

Other experiments managed to rapidly change the location of a visual object during the millisecond interval of saccadic blindness that occurs with movement of the fovea three or four times each second. Once again, the visual hand detects changes conscious vision can't. Anatomical investigation reveals a neural link from the brain's vision center to the motor functions of prehension. Neurologist Charles Sherrington suggests that the brain treats the sensitive skin at the tip of the thumb and index finger as it does the sensations of the macula, the most sensitive portion of the retina. It is not just that hand and eye *can* work together; there's almost no skill that doesn't combine them. We set things up that way, building an environment that takes advantage of the synergy of hands and vision. That includes visual art, as we'll see.[26]

People accomplished in technical design have felt the subconscious synergy of eye and hand. Walter Chrysler, a machinist before founding his automobile company, wrote, "What I learned with my fingers and my eyes together I seem never to forget." James Nasmyth, nineteenth-century engineer and inventor of the steam hammer, said, "The eyes and the fingers—*the bare fingers*—are the two principal inlets to sound practical instruction. They are the chief sources of trustworthy knowledge in all the materials and operations which the engineer has to deal with."[27]

Whether it is the choice of grip, the manipulative strategies, or the use of tools, freedom of action radiates from the hand, creating a corresponding value for good choice. An unspecialized, somewhat fragile hand like ours would be a liability without the neurology we bring to the hand's mechanical affordances. It takes choice to operate this hand. There are no programs. That is not only true of hands. Cinematographic analysis reveals that the same acts performed under the same conditions are composed of different motions every time. Even highly skilled action is never performed the same way twice. At the fine-grained level of muscle enervation, no two gestures, no two purposeful acts, no two performances are the same.[28] The idea of a neurological "motor program" driving action is therefore probably misguided. In the movie *The Matrix* people get *kung fu* from a computer program, but the "knowledge" they acquire is only good *in* the Matrix—strapped

at the terminal, the bodies do not move, nor do they retain their virtual skills unplugged. We don't learn skills that way, by acquiring programs. Intelligent, deliberate, and especially skilled action is not built up from prefabricated routines. As Raymond Tallis observes, "While we accept that practice makes perfect, we have no idea how. . . . Every action is a unique part of an unfolding network of actions and the net is constantly billowing in the wind of external contingencies and internal attention-driven whim."[29]

Prior to the evolution of speech, when they were overtaken by the tongue, hands enjoyed the most advanced voluntary control of any body part. The more important hands become, the more they contribute to the evolution of the neurology that implements them. Surviving the creative burden of unrestricted opposability transformed the hand into an instrument of functionless functionality. Hands have long since lost any function for which evolution may have adapted them. A hand can grasp, though that's not its function. It can sense and communicate, though neither is its functions. Nothing could be more functional than hands, yet they have no function.

Tools inherit the functionless functionality of the hands that make and use them. What is a knife for? What is a screwdriver for? There is no answer, no proper function. Tools are, of course, made with use in mind, but they are radically defenseless against anyone who wants to use them another way, as we routinely do (fishing an earring from a drain with a knife, opening paint cans with a screwdriver, and so on). That's the difference between the functionality of tools and the function of evolved adaptations, and it begins with hominid hands. A heart, liver, or blood cell is useless (to the organism) for anything other than its evolved function (although what this function is may change with evolution). Tools could not be more different, a difference hands make. Like a hand, a tool's functionality is without function. There is more to say about this interesting property of functionless functionality, which I postpone to the next chapter.

A tool can't be an instrument without being more than an instrument. To think instrumentally, one has to be able to think the purposes of others; one has to understand that others are purposive beings like oneself, with beliefs, desires, and a point of view. In a moment we'll see why that is exceptional social cognition, without analogy in other primates. Instrumental cognition is a moment of social cognition and a spandrel of socialization. A crucial part of what we have to understand about others is their alliances with artifacts of many kinds (for example, tools and materials). Not to grasp that is to be, as it were, technically autistic. To understand others, you have to understand tools; to understand tools you have to think instrumentally; and to think instrumentally you have to have the hand of a biped running a neurology predisposed to impute intentionality to others. Technical thinking is therefore simultaneously an achievement of instrumental and social

cognition. Yet social cognition is older and enjoys priority. Could we not think the other's purposes, we'd have no grasp of functionless functionality; consequently, no tools, language, conventions, or culture.

## Neurology

> The conventional view that natural selection favors nervous systems which produce ever more accurate images of the world must be a very naive view of mental evolution.
>
> Robert Trivers

We come last in a genus whose species have been evolving bigger brains for the last 2.5 million years. A much larger brain is nearly all that distinguishes the earliest *Homo* from an australopithecine. *Homo* evolution eventually achieved a threefold rise in cranial volume and a fourfold rise in neocortical surface area by folding.[30] This "encephalization" (the technical name for evolving brain size) is not a trend in australopithecine evolution, nor in primates generally, *Homo* being the exception. Australopithecines followed the path of other large African mammals, evolving specialized chewing works and becoming browsers. The new genus *Homo* is a different experiment in African survival. The jaws go the other way, becoming lighter, as part of an overall lightening of the skeleton. Instead of big jaws and a taste for browse, *Homo* goes for light build and bigger brain. From this evolution we inherit a neurological indeterminacy and plasticity that should be the death of us were it not for artifacts, or culture in its effective form. The evolution of technical culture does not merely parallel the evolution of neurology; the processes lean on each other and co-evolve. Technics enhance the sheltering carapace under which to grow a bigger brain, whose effects include the expansion of culture.

John Locke thought the mind began as a blank slate. Apart from a few rudimentary associative algorithms, there is nothing to the mind but what experience puts there. The historical alternative to this empiricism (associated with rationalist philosophers like Descartes and Kant) is that the mind has a necessary, a priori structure. We don't think as we do because of our experience; instead, the basic forms of experience are universal and inescapable. By the end of the nineteenth century Darwin offers a dramatic alternative. For "mind," read neurology. This deeply complex biological system is the product of long evolution. It does impose its own structure on the stimuli it has evolved to respond to, schematizing experience from the beginning, a priori, as rationalists said. Yet these structures are evolutionary and thoroughly contingent, not logical or rational. They correlate with ancient ecology and historical survival, not transcendent reality and contemplative truth.

We understand this neurology better today than Descartes or Kant did, and the

results substantiate neither rationalist nor empiricist conceptions. It would be difficult to imagine a more inappropriate analogy for hominid neurology than the surface of a mirror. It is more like a willful animal, stubborn in its preconception about how things have to be. Here is a sketch of the cognitive profile of the modern human neurology:

- Stubborn, willful, Procrustean: selecting, synthesizing, analyzing, and reducing inputs to self-generated categories, preferring a forced fit over ambiguous uncertainty.
- Good with differences, thoughtlessly ignoring repeated and expected stimuli while responding eagerly to the new and unexpected.
- Hierarchical, integrating information from many levels, including reflexive self-calibration, operating on its own operations (for example, converting short- to long-term memory).
- Active: predicting, extrapolating, testing, manipulating input.
- Aesthetically motivated: constructing plausible, coherent, synthetic models with implications far beyond the data, for the beauty of which this brain is also generously self-rewarding with opioid peptides.
- Inherently social-cultural: a human neurology is biologically impossible apart from the economic resources of culture. That also means inherently artifactual since, as I mentioned, artifacts *are* "culture" in its effective form.[31]

If brain enlargement is so adaptive, you could wonder why it's rare in the hundreds of millions of years since the first neurons. I glean the outline of an answer in three considerations. First, consider what neurology is good for, what it does for organisms that have it. Neurons evolved as a strategy against environmental uncertainty. The major function of any neurological system is to integrate different kinds of information and different kinds of response into coherent action. These systems modulate everything they are connected to, whether proximately (other nerves or hormones) or distally (tools or other people). Oversized neurology therefore doesn't make adaptive sense except for a body-form already supplied with versatile distal effectors, like hands, and good visual and auditory perception. There's not a lot that spiders and moles could do with more brains if they had them. It was Darwin's theory, and remains the best account, that hominid brain enlargement comes *after,* not before, bipedalism and the freeing of the hands.[32]

Neurology only really becomes adaptive (relative to its high cost) under conditions of primate-like social life. That's a second consideration. A species has to be in a position to benefit from more neurology. Human ancestors apparently were. According to a plausible hypothesis, hominid brains got larger because with more neurology our ancestors were able to manage life in larger groups, from which they reaped the reward of enhanced predator protection and, eventually,

the adaptation of culture.[33] Organisms can't be packed beyond limit; at some point of concentration any population turns chaotic. It would be advantageous (especially to niche-thieving bipeds) to stretch the parameter and make the optimal group larger. Larger groups cover more ground without sacrificing security; and what our neurological innovations are really good for—language, art, myth, convention, exchange—greatly enlarge the potential size of a coherent community.

Then there is the problem of exactly how to go about growing a bigger brain. The relative size of organs is a sensitive matter. No one part can simply get bigger. The entire organism must compensate, requiring changes in potentially every other part, with all the ramifications that must have for a species' way of life. The dimensions of the birth canal put an absolute limit on the size of a newborn's head. No primate, bipedal or not, was in a position to experiment with encephalization until this limit was overcome, as it eventually was, by *an evolution of development.* What most fundamentally evolves in hominid neurology is not neurology per se (neural tissue); instead, it is the process of its growth that changes. What is peculiar about this neurology is not its finished form but how it develops. It grows much longer than that of other primates, a characteristic developmental biologists call hypermorphosis. For instance, three days more growth in founder cortical cells results in a tenfold increase in adult neocortex.[34] Our evolutionary ancestors took the infant's head to the limit of the female passage, and then stuffed it with neurons that keep growing—fast—for years after birth. I do mean fast. Early postnatal neural development has been clocked at 250,000 neurons per minute, with 30,000 new synapses per second for every square centimeter of cortex for at least a couple of years.[35]

Not every animal that has a nervous system is in a position either to grow a bigger one or benefit from more of it. A number of contingencies coincided to put our ancestors in that position. We evolved larger brains because the bigger they grew the more adaptively we could use them—initially, perhaps, for enhanced social cognition which, as I suggested, is also the origin of instrumental cognition. We didn't stop until we had a brain that could leave off the biological route and pursue its survival "artificially," by artifice and design.

## Cognition

> In some remote corner of the universe, there was once a planet on which clever animals invented cognition. It was the most arrogant and most mendacious minute in the "history of the world"; but a minute was all it was. After nature had drawn a few more breaths the planet froze and the clever animals had to die.
>
> Friedrich Nietzsche

This is not the place, and I am not the author, to survey everything known or surmised about cognition. However, I do want to discuss two distinguishing quali-

ties of the human cognitive style. One is sharing attention with others on a common object. The other is our knack for making artifacts do some thinking for us. These two strategies of cognition distinguish human beings among primates, and are genealogical conditions on instrumental thinking and the use of tools. I begin, however, with perception, to make the point that perception *is* cognition, not a precognitive, preconceptual datum.

## *Perception*

> In looking at an object we reach out for it. With an invisible finger we move through the space around us, go out to the distant places where things are found, touch them, catch them, scan their surfaces, trace their borders, explore their texture. Perceiving shapes is an eminently active occupation.
>
> Rudolf Arnheim

Experimental research confirms that perception in all its modalities (vision, audition, and so on) is gradual and takes time, developing from detection, to generic identification, to a completion of the perception, with or without consciousness. The whole brain is involved, from cognitive centers and circuits to emotion, motor areas, and memory. Experimental psychologist E. B. Titchener is supposed to have said that you can't show a person wallpaper without disturbing respiration and circulation. Affective feeling accompanies practically any perception, and almost any stimuli have some motivating effect, as revealed by the physiological indices of arousal, including skin conductivity, dilation of blood vessels and pupils, and a rise in muscle tension, heart rate, and respiration. Concurrent with perception, orientation reactions adjust our receptors (focusing eyes, cocking an ear), while chemical changes in the organs increase their sensitivity. All of these processes and systems cooperate to enhance our capacity to take in information and prepare for action, including further exploration at the source of the stimuli.[36]

Any perception involves computation and abstraction. For instance, the neural image existing in the eye at any moment is highly incomplete. There are blind spots, as well as regions of interference between blood vessels and light-sensitive receptors. There's constant distortion, including a drastic loss of peripheral detail, and continuous transformation of the image to generate constant color and shape despite changes in light or perspective. All of that demands cognition of a high order. Abstraction and conception start at the most elementary level of acquiring sensory data. Before neural signals have even left the eye, the "data" of vision have been worked over by a fast, intelligent optical system, and visual perception is as abstract and schematic as the most logical concept.[37]

Touch shows something about perception that's hard to see with sight. We know touch as an action; we watch ourselves and others do it, feel the reach out, savor the contact and manipulation. Vision is the same, though we don't see it, and

not only because it happens so fast. The most prominent activity of vision is selection, the rapid, calculated scattering of the fovea, the small area of the eye (1 percent) in sharp focus at any moment. This usually changes three or four times a second. There is a 250–300 millisecond fixation, interrupted by a saccade, or movement of the eye, and a new fixation. The illusion of completeness and constancy derives from these fast, frequent saccades, which keep a fleeting image constantly updated. I mentioned that during a saccade the entire visual system momentarily shuts down, a process known as saccadic suppression. It renders us totally blind for 10 to 15 ms three or four times a second.[38] The frenetic distribution of visual attention reveals the exertion vision involves, while the unnoticed discontinuity of two or three moments of total blindness every second proves vision's mediated, constructive (rather than immediate or receptive) character.

Vision is a furious cogitator, not the rapt attendee of self-showing phenomena. Novelty and perceptual complexity appeal to attention and exploration. Vision's nervous selectivity makes reaction faster and surer by restricting choice to preferred categories, a virtue of necessity for an eye whose focus falls off rapidly at the slightest departure from the axis of fixation. Nerves also determine the most prominent phenomenology of attention—the figure-ground structure of consciousness. Arnheim explains, "Because retinal sensitivity is so restricted, the eye can and must single out some particular spot, which becomes isolated, dominant, central. This means taking up one thing at a time and distinguishing the primary objective from its surroundings."[39] It is this evolved visual regime, and not the inherent structure of reality, that lies at the origin of the philosophical concept of an *object*—something "out there," bounded, individualized, a figure against a ground.

### *Shared Attention*

A benchmark synthesis of comparative research on cognition across the primates reaches an important conclusion. The most prominent difference the authors find between human and nonhuman primate cognition is the human infant's quickly developing ability to understand others as intentional agents pursuing goals and choosing means.[40] From at least the first year children understand how intentional action is organized and have learned to attend to others as agents, monitoring *their* progress toward *their* goals. By eighteen months they are adept at inferring others' intentions before imitating what they do. For example, they will remember a word as referring to what the adult was looking at in saying it, not what the infant was looking at. If an adult tries something and fails children will imitate what the adult tried to do, not what he or she did, and if the adult indicates that an action was accidental ("*Oops!*"), children will not imitate, though they will if the same action is presented as intended.[41]

This is all quite different from other primates, chimpanzees and bonobos included, who relate to each other as animate and directed but not intentional. Social intelligence in *Pan* seems not to rely on a psychological model of the other. They regard neither others nor presumably themselves as agents with interlocking, hierarchal purposes and a point of view. The one specifically human cognitive adaptation appears to be to grasp the other's intentionality. Our thinking would be a lot more like a chimpanzee's were it not for this naive imposition.[42] The discovery of the other's intentionality is probably a precondition on the use of language, while tools presuppose instrumental thinking learned partly by the need to master our hands, and partly to understand what others expect to happen, especially from the use of artifacts.

Primatologist Michael Tomasello, one of the authors of the comparative study, thinks this capacity to read others' minds is not a spontaneous extrapolation of self-feeling; it is the development of a more basic capacity for shared reference, sharing attention with others on a common object. Infants begin to share attention and imitate from the age of nine months. A whole set of joint attention behaviors emerges at this time, including pointing for the other, and a deictic (pointing) gaze (eye movements alone can direct an eighteen-month-old's attention).[43] Normal development requires abundant opportunities for an infant to engage in intentional back-and-forth with others, learning to read and imitate their beliefs, desires, and emotions. There is nothing like this continuous reciprocal signaling in apes, and it is crucial for learning how to convey intent and respond to signaled intents rather than action.[44]

Ontogenetically and phylogenetically, development seems to run from understanding others as animate and directed (common among primates), to intentional agents (humans by the first year), to intentional agents with beliefs and thoughts that may not be expressed (by the fourth year). The capacity to read others' minds, which implies anticipating perception from multiple perspectives, does not require language, though it is much enhanced by it. With every word language imparts the lesson that there are different ways of describing any situation. Language is intrinsically perspectival, signifying by means of the contrasts or differences among possible descriptions. What others say they select from these possibilities, presumably motivated by an intention to communicate. Linguistic symbols are therefore intrinsically intersubjective. My use of a word depends on my understanding that others use it in a certain way, and speech is an ongoing, nuanced adjustment to the way interlocutors construe each other's behavior.[45]

Darwin plausibly supposed that the social environment has been the most powerful shaper of human adaptation. It's plausible because the greatest threat to a human being is another human being, as the most dangerous threat to groups is other groups. Darwin therefore expected natural selection to favor both intel-

ligence (for war) and solidarity (toward "your" people). Individuals incapable of homing in on others' purposiveness would be unlikely to survive this demanding cross-selection. So it's not surprising that human beings are specialized from infancy for social-intentional cognition. The extraordinary demands of neonatal neurological development are so urgent, so utterly required for the development of anything we can recognize as a human being, that we have to be born to get along. In this respect we are for good and all what Nietzsche called herd animals.

Every social species deals with social life in its own evolved way. Ours was, in part, cognitive. Our take on primate social life depends on the intelligence to understand others' goals, plans, and intentions, and the sympathy and solidarity cooperation requires. We're so successful at it that we've made practically all the problems of survival into social problems. Technical, social, and ecological conditions are not sequestered but synergistic; in practically any situation, effective, intelligent action requires identifying the intentions of others.[46]

Primates stand out cognitively from other mammals for their understanding of relational categories; for example, understanding that one animal is more dominant than another. For them, this thinking is primarily social, though under laboratory conditions it can be brought to bear on physical relations. Human cognition apparently builds on the primate understanding of relational categories, adding the idea of causes and especially purposes. Causal understanding evolves first in the social domain, in the comprehension of others as intentional agents. The causal understanding of physical events extends this originally social cognition to the point where there's almost nothing we won't treat as if it were a person and had a purpose or design.[47]

We understand a motive before we understand a motor. We understand the designs of others before the design of a device. Yet we cannot grasp the plans and purposes of others without at some point understanding the facilitation they expect from instruments and their effects. On the first cognitive horizon we see the Other and appreciate mutual intentionality; then comes the horizon under which the things others enrol their goals *also* have a sort of intentionality. They were *made* by others, made to facilitate goals, have designs and purposes like a person. We grasp the artifact as a metonymy of the Other. We quickly appreciate its human qualities (useful, collaborating, working). Each new generation grasps these pliable nonhumans as black boxes they simply use (chapter 2). They make sense, like a person, but behave as sources of functionality to recruit into a plan rather than someone to talk to. They can have unnatural presence, standing out like a beer can in the wilderness. Tools especially, which practically call out to be touched, picked up, addressed by the hands in some way. Their presence and our

response make the works of artifice and design more like other people than indifferent physical objects. We expect them to make sense, and when they don't, when they are disturbed or unpredictable, we try to repair both our machines and our relationships.[48]

Artifacts are the other Other. With the extension of intentionality from others to the works they work with, intersubjectivity and artifice become two strands in a socio-technical economy of enormous complexity in even the simplest societies. More humans collaborate with more nonhumans, which acquire more human qualities, and collaborate more intensely with other nonhumans too.[49] I suggest that this complementarity, at once social and artifactual, is the foundation of technical economy, the economy tools presuppose, and it is what's missing from the proto-tool behavior of chimpanzees.

### *Cognitive Artifacts*

It's not unusual for organisms to change their environment so as to generate cues to an adaptive response. Ants do that with pheromone trails, which communicate information about direction and distance to a food source.[50] Our way is with artifacts, things made from made things. Our perception and cognition are extended, supplemented, and amplified by the introduction of artifacts designed to work with preferred ways of seeing and thinking. Cognition roams abroad, accompanied by a pair of hands and a box of tools, and leaves a trail not of pheromones but artifacts, some of which are designed and constructed to facilitate the cognition required to use them.

These cognitive artifacts may be as simple as a shopping list. Instead of remembering, we write it down (or write it down as a way of remembering). Tools store information about how to make them—they, and not ideas in the head, are the templates for making other tools. Language must have greatly extended collaboration in cognitive artifice, though our knack for thinking through artifacts equally presupposes hands. That's as true today as a million years ago, as true of a computer as a stone blade. Any artifact is ultimately handmade, a work of *ars* or *techne*. Take away the hands and technics make no sense.

The relation between memory and writing is almost symbiosis, except one of the partners is an artifact rather than another organism. With the art of writing an infinitely expansible external memory becomes the real working memory. Cognitive artifacts like pencils and paper (to say nothing of computers and cellular phones) distribute and extend thinking to external things, especially other artifacts. Cognitive psychologist Merlin Donald writes, "Each time the brain carries out an operation in concert with the external symbolic storage system, it be-

comes part of a network. Its memory structure is temporarily altered; and the locus of cognitive control changes."[51] The Internet was implicit in the first script, which does not come at the cost of memory, as Plato feared. True, memory is no longer completely subjective—we make artifacts do it for us. Yet all we lose is the contemplative illusion that conscious, subjective memory depends on nothing but the mind's own life. We understand, as Plato did not, that without the body, its intricate machinery a contingent outcome of undirected evolution, there would be no mind, soul, or consciousness at all. Is it a stretch to allow that an artifact might do some thinking for us?

Poetic meter is another example of cognitive artifice, much older than writing.[52] All recorded peoples practice some art of metrical speech. To appreciate its cognitive potential, we need an elementary description of what meter does. Call the fundamental unit of any meter a *line* (not that it need be written, of course). This line has some important properties regardless of which culture or historical period we sample. For instance, it takes 2–4 seconds to recite, with a strong peak between 2.5 and 3.5 seconds. What fills the duration, in whatever language is spoken, is a coherent unit on three levels—rhythmic, semantic, and syntactic. The line will also consist of marked and unmarked elements of many kinds—number of syllables, stress or cadence, alliteration, consonance, rhyme, and so on—which remain constant. The 3-second (average) line is thus distinguished from others by the pauses that surround it, and linked to earlier and later lines by the repetition of marked elements.

Metrical patterns are cognized in the right cerebral hemisphere, while understanding poetry, as spoken language, is primarily a left temporal lobe process. Metrical speech thus integrates right- and left-brain processing. The synchronization of sound and sense goes further, though I need to mention something about auditory perception. Sounds less than 0.003 second apart are perceived as simultaneous. To perceive a sequence, sounds must be at least 0.03 second apart, while intervals of 0.3 second allow time to respond to the sound. To provoke a response requires enough time for a reaction, but also requires some intimation of purposiveness in the sound, quickening our socially tuned cognition. Finally, three seconds is the approximate length of our auditory present moment, the auditory buffer, or what introspectionist psychology called the specious present. When we speak, we make millisecond pauses about every three seconds to prepare the wording of the next three-second burst, and auditors take in about three seconds worth of speech, then briefly stop listening and make sense of what they just heard. We do this as seamlessly and unconsciously as we update vision by a barrage of all but instantaneous foveal saccades.

I'll let the authors of the research I've been summarizing draw the connection

between what they discovered about meter and what they learned about auditory cognition:

> A remarkable and suggestive correlation exists between the temporal organization of poetic meter and the temporal functions of the human hearing mechanism . . . [T]he length of a syllable, about 1/3 of a second, corresponds to the minimum period within which a response to an auditory stimulus can take place. To be efficient, speech must be as fast as possible, while, to be controllable, it must be slow enough for a hearer to react to a syllable before the next one comes along. . . . [Also significant] is the very exact correlation between the three-second line and the three-second "auditory present." The average number of syllables per line in human poetry seems to be about ten, so human poetic meter embodies the two lowest frequency rhythms in the human auditory system.

"Poetry," the authors say,

> presents to the brain a system which is temporally, rhythmically, and linguistically hierarchical and, therefore, matched to the hierarchical organization of the brain itself. It does much of the work that the brain must usually do for itself by organizing information into rhythmic pulses, integrating different types of information—rhythmic, grammatical, lexical, acoustic—into easily assimilable parcels and labeling their content as belonging together.[53]

Meter is not keyed to *breath*—the crucial rhythms are neurological, brain rhythms. Meter makes lines that mesh with the auditory buffer and mobilize both cerebral hemispheres, simultaneously enhancing the speaker's capacity for memory and the audience's capacity for rapid understanding.

Another example of cognitive artifice, this one distinctly modern, is photography—the making of photographs. To look carefully at photographs can be more useful in the sciences than to contemplate nature directly. Philosopher and sociologist of science Bruno Latour observes, "Scientists start seeing something once they stop looking at nature and look exclusively and obsessively at prints and flat inscriptions . . . , two-dimensional images which have been made less confusing." Not all these inscriptions are photographic, though many are. Photography is a technology equally of detection and depiction, and easily combines both. Its technology, including digital imaging, amplifies what a philosopher of the photographic calls our capacity "to detect situations on the basis of surfaces we have contrived to let them mark."[54] That is a variety and family of cognitive artifice.

The photo-imaging of ultrasound, nuclear magnetic resonance imaging (MRI), computerized tomography (CT), x-ray, and cognate technologies create an

appealing interface for vital information that would otherwise be difficult to assimilate. Such photographs capitalize on the extraordinary artifice of *imaginary detection*—reliable detection performed by an act of imaginative vision. When we look at, say, an ultrasound photograph of a fetus, we look at marks that an ingenious apparatus extracts from an ensemble of collaborators human and nonhuman. We look at those marks and *imagine* that we see a fetus. This photographic fetus is as imaginary as the apparent extension of an arm drawn with foreshortening. Nevertheless, the imaginary condition of this image correlates quite precisely with conditions of the fetus that the apparatus detects. The cognitive artifice of the photograph is to let us see that by imagining that we see it.[55]

Human beings don't have a purely biological bit and a bit added by social relationships, language, or the accoutrements of culture. Instead, what we biologically are requires that we're decked in those accoutrements. That's no less true of our brain than our hands. We have the brain we do because of the social form of life we have, and vice versa. Our brain is adapted to work with others, as it is to work with artifacts. Any locale of human life is strewn with things artfully crafted to expedite perceptual, cognitive, and motor engagement. Besides those discussed, these artifactual complements to cognition include formal organizations (offices, factories), and such artifacts as numerals, diagrams, schedules, signs, and clocks. These are examples of how we arrange for artifacts to do some of the processing required to solve a problem. By their means we offload computation and remake ecological, social, and technical environments according to cognitive preference.

## Language

Language requires an improbable conjunction of adaptations in cognition, social life, anatomy, and physiology. The use of language was probably preceded by some form of shared, social attention to a common object. As we've seen, that is no commonplace cognition. Also, language is organized by conventions—the only reason to speak as we do is because others do too. Convention is unsustainable without some predisposition for trust and reliability, for which naturally selected reciprocal altruism and what Darwin called our social instincts prepare us. Not just any brain can learn a language, not even a chimpanzee's brain, which is otherwise rather like ours, and whether spoken or gestural, language requires preadaptation for fine serial motor control (fingers, tongue).[56]

Contingent converging changes in anatomy, cognition, and social life almost make language appear heaven-sent, though that is not a possibility I pursue. For many years, the usual explanation of language—usual before Darwin and since—was Darwin's own: language is an adaptation, purposive and functional,

*for communication.* Of course, Darwin adds that this purposiveness is generated by a mindless process of natural selection. He considered language to be a gradual modification of the communication systems of monkeys and apes. He knew of the vervet monkeys, with their repertory of calls indicating different predators—a call for eagle, python, leopard, and so on. Is it not thinkable, he asks, that in the evolutionary past "some unusually wise ape-like animal . . . imitated the growl of a beast of prey, and thus told his fellow monkeys the nature of the expected danger? This would have been a first step in the formation of a language."[57]

Comparing language to these communication systems is probably a mistake. They aren't that similar. Consider some of the differences. Animal call systems are good for nothing but communication, whereas language has other important uses; for instance, to store information and be a medium of cognitive artifacts. You can't store information in a vervet call system, not even a little bit. The difference is categorical. Give übervervets a million calls for a million things, they still can't use them to store information or think anything through. They are limited by the associative, indexical connection between call and referent, which has none of the flexibility we get from words that are not associated with anything at all, the synthesizing, syncategorematic words of logical syntax, like *not, some, each,* and *if.*

The screaming vervet performs no speech act. The calls are isolated signals, fixed sequences without the syntax of a sentence. There is no recursion, that is, no units recurring in combination; no grammatical or ungrammatical combinations; no marks of plural or tense. Vervet calls apparently operate as Darwin thought—the caller's spontaneous emotional expression has become an adaptive signal for everybody else. All a monkey can do with this system is involuntarily express a discriminating fear of predators and, being monkeys, raise a false alarm to manipulate others.

Language is very different. It is an open system. Speakers can add new items at any time, even (as you see) in midstream, without hopelessly losing the thread. The limitless capacity to juggle signs for anything is without comparison in animal communication. This open-system quality derives from the same source as language's flexibility. It is the words and markers of syntax that prepare the place for an open-ended, flexible reference to objects. Without syntax, animal communication is locked in the here-and-now. No animal call has the sense of what *did not* happen, what *is not present,* what *could have been.* Neither does an animal call refer to the past or future, or to places where the animal has never been.

Obviously we use language to communicate. But that is not all language is, and probably not how it began. The reason to doubt such an origin is, again, syntax. You just don't need it for adaptive communication. Syntax is expensive. It is all cortex, the newest, most resource-intensive part of the brain. If all we used

language for is what apes already do without it, why incur this cost and evolve syntax at all? It is usually assumed that full-blown language first appears with anatomically modern *sapiens* about 160,000 years ago. It is unsatisfying to think of language appearing all at once in its modern-human form. The thing about syntax, though, is that you can't have just a bit of it. The simplest syntax has all the qualities that make language practically impossible for other species to learn. So how do we pass from no syntax to syntax without intermediate forms?

That's the attraction of the protolanguage hypothesis, a partial solution to the puzzle of syntactic evolution. Protolanguage is a communication system situated between language and animal call systems. There's nothing merely speculative about protolanguage. It can be defined formally, and shown to be the system in use by children under two; adults deprived of early language or speaking pidgin; and appropriately trained apes. These contemporary protolanguage phenomena suggest that there may have been a protolinguistic phase of hominid evolution. What's speculative or hypothetical about protolanguage is projecting it back to a time before there was any language at all.[58]

Protolanguage is easiest to describe by invidious comparison to language—it lacks syntax. Protolinguistic speech is a linear string of lexical items, without grammatical particles, inflections, or auxiliary verbs. Word order is a function not of syntax but overall meaning. Inferred reference is formally ungoverned and can appear anywhere, the referent fixed not by syntactic rule but by communication intention and context. That makes protolinguistic reference indexical and associative rather than symbolic. There is no recursion, no unlimited expansion of phrases, no combinatorial complexity at all. The rate of utterance is slow and hesitant, unlike spoken language, where the median rate is one hundred words per minute with negligible hesitation or self-correction. One can usually understand something of speech regardless of context, but not in asyntactic protolanguage, which is virtually uninterpretable out of context. Something like half of the words (tokens) we actually use are syntactic items referring to the structure of our own utterances. If without any further context you encounter the sentence "Jack thought Joe said no," you have no difficulty understanding that at some past time, Jack (whoever he is) believed Joe (whoever he is) denied or declined something. Even that much would be impossible to conjecture from protolanguage sequestered from working communication.[59]

The cognitive and semiotic singularity of language is syntax, meaning rules by which changes of word form correlate with changes in reference and truth-value. It is syntax, a very specific sort of "complexity," that makes language practically impossible for other species, and it is syntax for which human neonates are dramatically preadapted. Its cognitive demands are steep. Key is the capacity to correlate change in one dimension (language sounds) with change in another

dimension (say, the visual field). Cognition of this sort is primarily performed in the prefrontal cortex, which just happens to be the outstanding neuroanatomical singularity of human brains among primates, with six times the prefrontal cortex of chimpanzees despite an only slightly larger body.

Derek Bickerton, the linguist who introduced the protolanguage hypothesis, sees the evolution of language in two main stages. The first is the emergence of protolanguage with *H. erectus* about 1.5 million years ago. Probably this protolanguage was developed (to the extent that it can be developed) by later species, including Neanderthal. The second phase of neurological evolution comes with *sapiens* and the supercharging of protolanguage with syntax. It need not require a large neurological change to make a protolinguistic brain grow its own syntax. The processing that syntax systematizes already goes on in the protolinguistic brain. All that's lacking is a dedicated network of connections to bring it together in the cognitive artifact of syntax. On the other hand, in a brain like ours there probably is no such thing as a "small" change.

Even with a hypothetical protolinguistic phase of evolution, there is still discontinuity in the emergence of language because, as I said, you cannot have just a bit of syntax. A brain that thinks syntactically at all thinks like ours. A further palliative against discontinuity is that the potential complexity of a language need not be expressible in the words people actually learn to use. To form a language system, signs have to be syntactic, but syntax is largely a projection of lexicon. If the lexicon is drastically limited, as is likely in first language, then not all structures implicit in the syntactic principles (for instance, counterfactual or fictive discourse) would be realized.[60] The last discontinuity separating language from protolanguage may have been overcome in evolution the same way children overcome it today. What linguists call a pidgin is the asyntactic protolanguage that emerges when adults have to communicate without a common language, hence pidgin's reputation as the jargon of the entrepôt. *Creole* is the name linguists give the languages children raised in a milieu of pidgin "learn," or rather construct for themselves. A creole is a language that arises spontaneously when children hear pidgin and fill in the rest. Perhaps that's also what happened in evolution. The first mutant *sapiens* would have grown up in a milieu of protolanguage, which had probably been part of hominid culture for thousands of generations, perhaps since *erectus*. The first language would have been the creole these first sapiens linguists *invented for themselves* (as children do today) on exposure to the pidgin protolanguage of their elders.

There was thinking before there was language, as there is thinking in animals without language. But thinking cannot go far without language, because it cannot go off-line.[61] On-line thinking works over neural responses continuously elicited from the environment. This is the thinking that gets you from A to B.

Off-line thinking involves cognition directed upon its own products. Unlike vervet calls, protolinguistic signs would already have to be decoupled from circuits that precipitate immediate behavior. That opens the way to "off-line" thinking, a lapse into self-referring feedback when cognition becomes preoccupied with its own operations. A developed protolanguage facilitates feeding cognition back its own products, and language (syntax) enhances the process. Thoughts acquire a perceptible, memorable form, which allows thinking more effectively to perceive itself and direct thought according to a purpose. Eventually the system of internal reference reorganizes itself syntactically, creating the first full-blown languages.

What is probably right about the idea that language is for communication is that that was the adaptive origin of *protolanguage.* But the step to language, the step into syntax, looks more like post-protolanguage selection for the enhanced cognition linguistic concepts make possible and the then-new practice of symbolically amplified thinking; what language is "for," then, is language, or linguistic thinking. Thought and language are different, but everything that advanced language advanced thought. A perceptible, spoken form reifies fleeting cognitions, allowing thoughts to be shared and repeatedly thought over, criticized, corrected, and updated. With speech we can attend more carefully to the thoughts we hear ourselves and others express, what we remember others having said, or what we consider saying before we speak. Language thus powerfully enhances what off-line, reflective thought requires—a delay or buffer between receptor and effector systems. That creates cognitive workspace for the signs of internal reference, a space of pure (purely symbolic) mediation, which is the matrix of judgment and the origin of the *logos.*

Off-line cognition bears on the account I give of the origin of art. One thing off-line thinking enables and language amplifies is second-order perception, the perception *of perception.* The output of the visual (auditory, etc.) system is fed back as input for off-line attention. This seems to me the primordial significance of *contemplation*—the off-line (and in that sense "disinterested") awareness of present perception. To produce it requires self-discipline and is probably an early moment in the genealogy of human self-consciousness. Monitoring the physiological indices of arousal shows that symbols can evoke the behavioral patterns associated with their signification. Even when not giving rise to motor responses, these instincts incite associated central brain processes. It takes cues and learning to inhibit the motor responses that would destroy contemplation, catharsis, or the aesthetic interest in a representation (part of us instinctively sympathizes with the rude cowboy who shot the villain from the audience in a traveling show).[62]

Off-line thinking is decoupled from automatic, no-choice behavioral response, enhancing reflective flexibility in the response to stimuli. We gain the possibility

of choice and preference, even the possibility, long latent, of an *art* of choice, which became the art in artifacts. The evolution of second-order perception is half the origin of visual art. The rest is technical—inventing techniques to translate these higher-order perceptions of our own perceiving into a material artifact that shows us how we see. Visual art is a synergy of manual technique and second-order perception. Its works have a technically mediated, artificial, artful presence, due to how they have been put together and made to look. Western philosophers discussed the capacity for off-line, "contemplative" thinking at least since the time of Aristotle, who called it *phantasia;* later names include *Einbildungskraft* (Kant) and *imagination* (Coleridge). These are terms for the second-order process of thought thinking thought, the movement of the concept, creating symbolic realities that can become more fascinating than the empirical realities they represent.

Perhaps imagination is a spandrel in the evolution of language, but language and visual art did not cross paths for a long time. The first clear evidence of it are paintings in the Chauvet cave, where the earliest works are 32,000 years old (figure 1.1). These works come more than 120,000 years after the advent of anatomically modern humans speaking anatomically modern language. Whatever language had to offer art took a long time to find, but when it happens the advance is at once artistic and technical, visible in the design of paintings as well as the design of tools. Apparently, the sort of thinking language enables—off-line, reflective thinking about the products of earlier (remembered or communicated) thought—is not initially directed to thinking out the technical mediation of purposes. But once it is—a change we can probably identify with the cultural horizon of the Upper Paleolithic—tools, like art, come under the influence of thought-out design. The cultivation of design in artifice (tools or paintings) is an example of how language puts artifacts (they may be paintings or stone blades) in a public realm of interpersonal attention and consciousness, objectifying them and allowing us to compare and establish values.

### *Hand-Made Syntax?*

The possibility that first language was manual or gestural haunts Western speculation, never fully convincing yet never convincingly dismissed. As I understand the manual-origin hypothesis, what originates with hands and gestures is *syntax.* The idea would be that syntactic distinctions like subject, predicate, tense, number, and so on are originally executed manually, by gesture, rather than on the vocal channel. Thus even if first language is manual, the earlier protolanguage was probably a mix of vocal and gestural. The move to spoken language is the move to an autonomous vocal syntax, which allows linguistic communication solely on the auditory channel, however much residual gesture accompanies speech.

Let me summarize the evidence for manual origins.[63] Primate digits were way ahead of tongue, lips, and breathing in coming under voluntary control. Apes lack the ability to interrupt or modulate a flow of air, which is found only in bipeds and diving mammals; in apes as in most animals breathing is coordinated with locomotion and controlled only with difficulty.[64] By contrast, all the apes, presumably including our last common ancestor with chimpanzees, have hands capable of elaborate unscripted variations, and can learn gestural protolanguage. Apes use communicative gestures in the wild, primarily in one-to-one situations. About thirty have been observed in chimpanzees. They are aimed at others, produced when the other is looking, and invite a response. That is notably unlike chimpanzee vocalization, which is involuntary and usually directed to the group.

Primate hands are therefore preadapted, as vocalization is not, to the complex voluntary serial motor sequences syntactic language requires. Finally, there is evidence from so-called mirror neurons linking hand and eye. These are systems of cells that activate equally in the performance of hand movements or the mere sight of them in others. Language areas substantially overlap areas controlling arm-hand movement. Brain imaging studies reveal that Broca's area (left frontal cortex) is at least as busy coordinating hands with vision as in the generation of speech, and manual sign language suffers the same impairment as speech from lesions to this area.[65]

Manual syntax would demand careful attention from the "audience." Hands are busy places as it is. The need for hands to generate syntax limits what both hands and language can do. With manual syntax as a point of departure, people would have a motive to explore more convenient alternatives, and of course there's a lot to be said for speech. Lacking the iconic quality of gestures (apart from usually facetious onomatopoeia), the advent of speech would thus advance conventionalization and facilitate the introduction of arbitrary units, opening an unlimited domain of symbolic objects to think and talk about.

I do not assume that the manual origins hypothesis is true or even likely, only that it is a serious possibility, which indirectly confirms the profound cognitive resources of the hand. In the manual origins account (as I imagine it), the capacity for language (manual syntax imposed on preexisting protolanguage) would be a naturally selected suite of adaptations, while *speech* (vocal syntax) would be a cultural, artifactual, historical choice, presumably from the time before the modern human diaspora out of Africa sixty thousand years ago. If that were true, it would make speech itself—the idea of speech, which is to say vocal syntax—a beautiful example of cognitive artifice: an artifactual system more efficiently distributing the cognitive load of linguistic communication. By displacing syntax from compulsory gesture, hands were free to become more completely hands and language more completely language.

## Knowledge

> The person of integrity does not just complete himself. He also completes things. Completing oneself is benevolence; completing things is knowledge.
>
> *Maintaining Perfect Balance* (*Zhong Yong*)

We often cite technological works as examples of our best knowledge. It is clear that millennia of technical skills and craft precede any development of science or scientific theory. It's also clear (I'll say more on this in chapter 4) that science is built on deep foundations of engineering and even craftsmanship—performative, practical knowledge that can seldom be explained in terms of the theory it implements. Philosophical theories of knowledge haven't taken the measure of these well-known facts.[66] These theories fix on statements and beliefs—symbolic, linguistic, propositional entities; they develop technical concepts of evidence, warrant, assertability, and justification, all to explain a comically small part of knowledge territory—the part that happens to be true.

This theoretical, logocentric approach, much favored in antiquity and never really shaken from later tradition, is counterproductive to understanding the relation between knowledge and the technical accomplishments of modern civilization. The ingenuity of technical culture, the range and depth of technical mediation, the multiplicity of artifactual interfaces in a global technoscientific network—all of that indicates extensive, powerful, ingenious knowledge. But this knowledge is seldom the application of a scientific theory, usually can't be formalized, and rarely climaxes in demonstrable truth. The best knowledge of our civilization is consequently all but unrecognizable in the epistemology of the epistemologists.

It may seem obvious that knowledge has to be true, but it's an idea with difficult assumptions. Of course, some part of our knowledge is true—I'm not saying knowledge can be *false*. But the problem with saying knowledge (or perhaps just the most important, most philosophical knowledge) has to be true is that knowledge must then have a form appropriate to the evaluation of truth, which is the form of a logical proposition. When logicians define "proposition," that's what they say—a proposition is whatever bears a truth-value, whatever has a form suitable to evaluation in terms of "true" and "false." So if knowledge has to be true, then knowledge has to be propositional. Anything that cannot be translated into propositions is excluded in advance from the territory of knowledge (or the philosophically most important knowledge).

The usual reply to this argument is to distinguish between *knowing-that* and *knowing-how*. Knowing-that is knowledge of truth, knowing that such and such a proposition is true. Other kinds of knowledge—knowing how to play the flute

or use a pay-phone, for instance—are neither true nor false, being instead habits and skills, *how-to* knowledge. I wonder whether these are really different knowledges. Have they nothing in common as knowledge? Why do epistemologists concentrate so lopsidedly on knowing-that, if knowing-how is knowledge too? There is no epistemology of know-how—of what is *knowledge* about it, or how it relates to the hypertheorized knowing-that. "There are many sorts of knowledge," says an epistemologist, writing conventional wisdom for students. "But only one, the knowledge that something is true, will be our concern."[67] Nontheoretical, nonpropositional, nondiscursive working craft or *techne* knowledge is allowed only to be set aside, effectively ignored.

The relationship between knowledge and my several themes—art, technology, artifice, design, human experience—seems worth looking into, but we require a change of direction in the theory of knowledge. Epistemological accounts try to say what knowledge is, its conceptual essence, which they try to capture in a logical definition of necessary and sufficient conditions for knowledge—any knowledge anywhere. As I'll argue later in connection with the idea of art, I don't believe there are such "essences." I don't have the metaphysical proof of this, because it seems to me the whole idea of "essences" is a relic of the time before Darwin, and I have difficulty taking the idea seriously. There is nothing eternal, necessary, or changeless to our knowledge, or our life, or the universe of which we are a moment. The idea of essences was conceived in antiquity, when nothing was known of phenomena that eventually produced our stochastic, evolving, contingent conception of the universe, including biological evolution and quantum-mechanical indeterminacy.

I suggest that the question of knowledge be posed from a different perspective, not that of essence and logical form, but one of value. Instead of beginning with the question *what is knowledge?* (what essence, concept, definition), I want to ask what good it is, what's the point? Why trouble ourselves with distinctions between knowledge and error, mistake, accidentally true belief, myth, illusion, opinion, orthodoxy? The question in this form is relatively new to philosophy, first posed by Friedrich Nietzsche at the end of the nineteenth century.[68]

I think the answer lies with the artifact and its importance to a human form of life. I made the experiment of thinking about knowledge as a quality of artifacts generally rather than limited to propositions. That seemed to get over the unhelpful dichotomy of knowing-how and knowing-that, allowing us to appreciate what is knowledge-like about both cases. Whether we say "knowing-how" or "knowing-that," we are qualifying artifacts, praising them for a desirable quality. Making a calculation, prediction, or reasonable statement is a kind of making, a kind of artifice with symbols. The quality of artifacts apparently implicated as knowledge seems to involve their standing up and standing out as artifacts. The

artifacts associated with knowledge are consistently of superior quality (though there is no one measure). Someone who can't play the flute well, or who can't bake or bicycle with any facility, won't be said to "know how" to do those things. Nor are those whose statements fail to stand up, to withstand refutation, said to "know that" what they say is true.

Knowing-how and knowing-that are not different kinds of knowledge, nor different "senses" of the word, nor different concepts. They are different ways of performing (well) with different kinds of artifacts. Knowledge is a kind of accomplishment, a sort of success in artifacts. There is knowledge wherever artifacts stand up, or perform superlatively. That seems to be what gives knowledge its point, answering Nietzsche's question. Why care for knowledge, why seek or prefer it? Because the good of knowledge, understood in the widest sense and without regard for dichotomies between theory and practice or science and art, lies in the value of superlative artifactual performance, "superlative" meaning not literally the best but of the best, of that quality. What makes knowledge desirable and worth cultivating is the enhancement it brings to the effectiveness with which we operate in an artifactual environment. The more we cultivate knowledge, the more life's economy assumes this character; the more it does, the more effective knowledge becomes.

Superlative in whose eyes, by what standard? Who gets to say what knowledge is? Well, no one, because something else than say-so matters. Artifacts intervene, interject, demand their rights. What proves knowledge is superlative artifactual performance, and what proves that depends on the work's context, especially its relation to other works. Works do not appear without history; their performance is evaluated by relation to that history. Whether a work performs superlatively depends on its relation to others, its place in a practice, a tradition, a socio-technical economy.

Knowledge begins as a quality of an artifact, material in the first instance. Symbolic artifacts like deductions, theories, explanations, or true propositions no longer take center stage in the theory of knowledge. They are no longer the central cases, the clearest examples, setting the standard problems. A bridge or a surgical operation can be as good examples of knowledge as any proposition of science. Nor is truth a universal, necessary condition on knowledge, or on the best, most philosophical knowledge. That doesn't mean truth has no place in our theory. I approach the question of truth as I do that of knowledge—ask me what these are, their essence, and I can't answer because essences do not exist. A more tractable though no less interesting question concerns the *what for?,* the *what good?,* which seems to lie in the value of people's truthfulness. What we want from truth, what we expect, is a statement we can count on *whatever our purpose may be.* We want a statement that holds up, *come what may.* Practically everything that makes truth

valuable in all the ways it can be flows from this quality of irrefutability or withstanding refutation, and it is that *performance* which qualifies a statement as superlative of its kind, in other words, as the accomplishment of knowledge, "knowing that."

Given an artifact appropriately evaluated in terms of "true" or "false," only then does knowledge have to be true. Truthfulness, withstanding refutation, is the performance that qualifies artifacts of logical statement as knowledge. That is not a definition of truth, a subject fraught with difficulties.[69] It's a suggestion about what we're concerned with, what we're expecting and disappointed to find missing, when we ask whether what someone said is true, or whether someone really knows and doesn't merely assume without knowledge. We want and expect a truthful performance from statements invested with the value of knowledge, and from those with the authority to say what is known. Truth is therefore part of the pragmatic universe of knowledge, but part only. Truthfulness is a variety of knowledge, not a necessary condition on all of it.

I can imagine someone wondering how knowledge could *begin* with artifacts. Don't you have to *know* something before an artifact you make is "superlative" or an expression of knowledge? How could I make an artifact that expressed knowledge I didn't already have? John Roebling's Brooklyn Bridge (figure 4.6) is a handsome structure and notable engineering too, an artifact of superlative performance if ever there was one. Well, if the bridge expresses knowledge, there must be knowledge that the bridge expresses. Whose knowledge is that if not Roebling's, where is it if not in his soul, and how could it not have informed and directed the work?

These questions presuppose that knowledge begins at the level of propositions and representations. If I can't say *what* knowledge, in propositional terms of true knowing-that, the bridge expresses, then it cannot be an expression of knowledge, or at least not the knowledge of interest to epistemology. That begs the question of adequacy for representational theories of knowledge. When knowledge begins in artifacts there is no guarantee that it can be translated into true propositions. No set of propositions, however true, is equivalent to the knowledge the Brooklyn Bridge embodies. I'm not saying the knowledge is ineffable. An engineer can tell a lot about the bridge, how it works, why it is significant engineering. But retrospective analysis is in no way equivalent to the knowledge the bridge expresses, which is as singular and nonrepresentational as the bridge itself is.

Of course the bridge cannot express knowledge unless there is knowledge of which it is the expression. There is, and it is it. To describe an artifact as an expression (of anything, including knowledge) is not to imply that it "ex-presses" a psychical state first arising in the maker's soul. To anticipate a discussion of chapter 3, expression need not be subjective. It can be impersonal and artificial. That

is what aesthetic theory calls *intransitive* expression. Expression is *transitive* when it refers to an object, typically an emotional state of the maker. I feel anger and slap the table. The slap expresses subjective feeling, which it may also communicate to others. Transitive expression is usually limited to behavior rather than artifacts, though the behavior need not be human.[70] When it comes to artifacts expression becomes intransitive. Like an intransitive verb, an expressive artifact doesn't require an "object," that is, a psychological state of the maker that it transitively expresses. Intransitive, artifactual expressiveness *begins with the work.* It depends on how the artifact is assembled, how it looks, not what the maker feels.

So too for knowledge. It begins with a superlative artifact. It is not concentrated in an idea that enjoys intentional existence independent of a finished work. The artifact is the *beginning* of the knowledge, the moment it begins to exist. An artifact of superlative performance is the primary materialization of knowledge; the coherent, effective synthesis that turns fleeting cognitions, heterogeneous perceptions, miscellaneous manipulations and materials into a work of knowledge. An expressive painting is not first created in idea, then mechanically translated to canvas. Neither is knowledge first present as an idea, then mechanically translated into an artifact. A superlative artifact like the Brooklyn Bridge required a designer of skill, intelligence, and experience, with ideas about bridges and convictions about engineering. But there is no verbal, propositional knowledge that is equivalent to the knowledge the bridge expresses, or that would allow anyone who knew only that to build at Roebling's level of accomplishment.

The presuppositions of knowledge are evolutionary, not transcendental. Knowledge presupposes our specific neurology, the outcome of a long and chancy evolution, and one whose salient characteristic in *sapiens* is to require the artifactual shelter of technical culture for adaptive neurological function. Ours is a neurology so conditioned throughout evolution by interaction with artifacts that it is now itself an artifact—an effect of artifacts operating over geological time. Knowledge is the product of interacting artifacts, including our neurology, and only *works* in an environment saturated with artifacts.

Knowledge today is what it was in the Stone Age. Knowledge starts from scratch in the superlative artifact. What changes are the artifacts. The history of knowledge is not a story of change in what we do internally—a change in methodology, epistemology, or logic. What changes are the things we think and know *with.* What's really different about knowledge today, or knowledge in modern technoscientific societies, is that there's an awful lot more artifacts to begin with.

In chapter 4, I'll explain why knowledge begins where art does—in the discovery of the principle of design, which is to say the principle that things can be more or less artfully put together. Superlative artifactual performance typically

requires design in both its moments, aesthetic and structural, anticipating how a work looks and feels as well as how it meshes with other works. Aesthetic design concentrates on perception. Structural design concentrates on means and mechanism. In a work of art these are united, whether it is a painting or a bridge. The fullest conception of the technical problem in design *includes* the requirement of aesthetic, usually visual work. Even carefully engineered technological works *work* in the full sense of the best work only when they work aesthetically, perceptually, expressively, as well as mechanically or structurally.

## Art and Technology

The expression *Upper Paleolithic* is a specialist's term for a series of stone, bone, and horn artifacts found in central and western Europe between about 40,000 and 15,000 years ago. These are the artifacts of the Cro-Magnon people, the artists of Chauvet and Lascaux, and the first modern *Homo sapiens* in Europe. The date of the presently oldest Upper Paleolithic site, in Bulgaria, is 43,000 B.P.. The next oldest, in northern Spain, is 37,000–40,000 B.P.. Early dates at opposite ends of the continent suggest a culture sweeping across Europe—already colonized by Neanderthal—in a few generations.[71]

The diagnostic qualities of Upper Paleolithic culture are, first, an apparently dramatic rise in the complexity, ingenuity, and artistry of tools. Nothing in the older Middle Paleolithic anticipates the innovations. Tools are now variegated, interrelated, and specialized as never before. For instance, there are now burins for making the small holes in hide that stitched clothing requires, as well as needles of bone and ivory, both implying the manufacture of thread and clothing. Stone blades are flat-backed for more efficient handling. They are sculpted by retouching with a soft hammer, and combined with other blades and handles by an art of cords and knots. Antler, bone, and ivory join the materials for making tools. These people had dogs, flutes, and oil lamps; they made beads and invented the arts of sculpture and painting.[72]

When the Upper Paleolithic first came into scholars' view in the nineteenth and twentieth centuries it seemed plausible to identify it with the biological emergence of fully modern *sapiens*. That would make us about forty thousand years old as a species. However, it eventually became clear that *sapiens* is an originally African entity, and existed in Africa for many thousands of years before making its way into Europe. The innovations of the Upper Paleolithic correlate with cultural, historical events, not genetic ones. Specialists began to distinguish *biological* and *behavioral* (*cultural*) modernity. It seemed right to infer that some distinctively human qualities, perhaps including knowledge and art, which are

not in evidence until the Upper Paleolithic, are therefore not naturally selected adaptations but historical contingencies, effects not of a species-wide struggle for existence but of historical circumstances and local opportunities.

Art, knowledge, our knack for the artifact—these are all outcomes of evolution. It's just that the evidence seemed to make them spandrels. Evolution made them possible but also left them latent, unexpressed potentials that had to be discovered and cultivated. It is only because we evolved as we did that we can master art and technology, even though we did not evolve (by natural selection) to be masters of either. It was a postevolutionary choice, a preference and alternative recruited into the economy of human life sometime after our first 100,000 years as a modern species.[73]

This argument makes a lot of the apparent gap between the biological consolidation of modern *sapiens* as an African species and the earliest evidence of "culturally modern" behavior. Newer evidence suggests that this gap may be the illusion of a focus on Europe. Recontextualizing Europe with Africa, and expanding the time frame from the last 40,000 to the last 300,000 years, diminishes the aura of unprecedented singularity surrounding Upper Paleolithic culture. Acheulian tools (figure 2.1), including the teardrop-shaped "handaxe," suddenly stopped being made in Africa about 200,000 years ago, and were replaced by the diverse tool traditions specialists call Middle Stone Age (MSA). Eventually, this technical culture included hafted microlithic blades, retouched points in regional styles, bone tools, fishing gear, distant trade, beads, and pigments. Many components diagnostic of the Upper Paleolithic in Europe are therefore present in the African Middle Stone Age tens of thousands of years earlier.[74]

Middle Stone Age technics first appear in Africa between 250,000 and 300,000 years ago. It is unclear whether these tools signal the arrival of a new species, though probably not *sapiens.* The date is 150,000 years before the earliest secure modern *sapiens* fossils. And early *sapiens* did not always use an MSA toolkit—sometimes we used Neanderthal's Mousterian tools. Modern human fossils from the Middle East, where we shared habitats with Neanderthal for thousands of years, are associated with stone tools that are, in the words of one authority, "wholly and classically Middle Paleolithic [i.e., Neanderthal] in character."[75] So there's not a strong case for associating the innovation of MSA technics with the biological emergence of modern *sapiens.* It seems more likely that the first MSA tools were the work of some so-called archaic *sapiens* species, a near- or proto-*sapiens,* perhaps even an ancestor in whose midst the first mutant modern *sapiens* evolved 150,000 years later.

Recontextualized in a history that includes Africa, the appearance of Upper Paleolithic culture is less dramatic but more plausible. These people's technics now look like a climactic synthesis of gradual, uncoordinated developments in

technical culture in Africa and its colonies (including Asia and the Middle East) for the last 250,000 years. Modern *sapiens* inherited an MSA technics, which apparently suited us until the time of the *sapiens* diaspora out of Africa about 60,000 years ago. In the Middle East, our forebears discovered the Neanderthal's Mousterian tools and readily copied them. The forebears of Cro-Magnon would have taken a version of MSA tools with them as they traveled from Africa into central Asia, whence they descended into Europe, armed with a highly developed version of the MSA point of departure.

The Upper Paleolithic is an amalgam of contextually and historically contingent behaviors, gradually assembling at more than one center, and not a unitary cultural totality.[76] There is no precedent for the Upper Paleolithic in Europe because its genealogy is African, the technical culture new only in that region. Technically and historically the Upper Paleolithic looks like a transcending synthesis of MSA trends, many of which were apparently long in practice by modern humans and their recent evolutionary forebears in Africa. Having acknowledged the antecedents of Upper Paleolithic technics, and favored gradual continuity over revolution—the "bolt from the blue" evolutionists must always question—let's not have the pendulum swing to an opposite extreme, and diminish the technical singularity of the Upper Paleolithic. Despite MSA precedents for many of its forms, the later technical culture achieves a level of design, execution, and integration well past earlier efforts. Much that seems tentative, unsystematic, and sometimes lost from MSA industry (for instance, hafting) becomes a secure, cumulative, and eventually common human inheritance.

The most impressive distinction of Upper Paleolithic culture is likely to be its innovation of the arts of painting and sculpture. Both appear early and are highly developed from the earliest time. Cave painting in Africa apparently doesn't have the antiquity of a site like the Chauvet Cave in France (before thirty thousand years ago) (figure 1.1).[77] This may be due to poorer preservation in Africa or an inadequate search.[78] It may also be that the art of painting was not pursued, that the arts were for a longer period limited to tools, weapons, ornaments, song, and dance. I see significance in the first evidence of plastic art (painting and carving) because of their technical demands. These arts, more than any earlier, are arts of design. They are technically assembled works, put together from choice, showing technique and style in how they're made and what they look like.

It is useful to distinguish aesthetic responsiveness or aesthetic *feeling*—the perceptual appeal of a face, artifact, landscape, and so on—from aesthetic *artifice,* which is the design and construction of artifacts to anticipate and appeal to their perception. Aesthetic responsiveness requires an evolved capacity for feeling and perceptual cognition (chapter 3). But to *make* a thing aesthetically appealing takes postevolutionary artifice and design. I can imagine evolutionary forebears having an aesthetic

**Figure 1.1** Lions hunting on the main panel in the End Chamber, Chauvet-Pont-d'Arc Cave, Vallon-Pont-d'Arc (Ardèche), France, circa 30,000 B.P. Photograph by Jean Clottes. French Ministry of Culture and Communication, Regional Bureau for Cultural Affairs–Rhône-Alpes, Regional Department of Archaeology.

response to mates, landscapes, or the color of food. If they decorated their bodies, as seems probable, they may have been making things with aesthetic appeal. But apart from oversized, conspicuously well-executed Acheulian stone forms, there is no consistent evidence of aesthetic artifice or design until about thirty thousand years ago. Design concerns the reliable effects of an assembly, effects both visual and structural or mechanical. Its primary concern is the interaction of parts in a more or less closed system (a "machine," but this would include a painting). The art of design is an art of synthesis, of construction—an assembling, orchestrating, integrating art, the very *art* of artifice. That may be why Michelangelo said that design (*disegno*) is what all the arts share, differing only in tools and materials.

I've suggested that technical design has two moments. One is aesthetic, anticipating the human, perceptual interface—how the work looks and feels. The other is mechanical or structural, anticipating the instrumental interface—how it integrates with others, its mechanics, materials, maintenance, and so on. These dual moments of design are not isolated motives under separate principles. Aesthetic and mechanical or structural design are equally "technical." We come to

care how artifacts interface with others because we think about how they interface with us, their aesthetic qualities, how they look and feel (including ugliness or painful inefficiency), and how that can be anticipated and controlled by design. The fledgling art of design in Upper Paleolithic painting and carving is the strongest early signal of what would long be the pattern in the history of technics. The pursuit of aesthetic effects has always, until recent times, been the engine of technological advance. Artifice is older than art, but it was from art that we learned what the knowledge of design can do for artifice. The people of the Upper Paleolithic represent the future as we came to know it. They started to stake their survival not just on artifacts, or cumulative construction, but on *design,* which reorganizes the economy of artifice as a practice of knowledge.

Changing the environment in adaptive ways (niche construction) is ubiquitous in nature.[79] Sometimes the changes have downstream consequences, when they enhance the ecology the next generation inherits; for instance, termites inherit the mounds that sheltered their larval state. Further specialization makes the downstream effects cumulative. This is apparently limited to hominids, perhaps just to species of *Homo.* With cumulative construction, a ratchet-like process of discovery-spread-improvement-spread advances each generation's starting point. Chimpanzee tools have to be rediscovered each generation. It seems likely that cumulative construction requires the social cognition that differentiates human beings from other primates, and underlies our capacity for cooperation and high-fidelity imitation. In an ecology of cumulative artifice, the sociogenetic time scale becomes important for the first time in evolution. Situated between the ontogenetic time of individual development and the phylogenetic time of species evolution, sociogenetic time—or what we may as well call *history*—is the temporality of social learning and the transgenerational modification of skills, techniques, and other artifacts.[80]

Well before the Upper Paleolithic, cumulative niche construction had become technical culture, and from that point—a culmination and threshold, not an unprecedented innovation—this culture is increasingly one of *design,* which is to say a culture of art and knowledge. Technical economy adjusts to the demand for superlative artifactual performance. It is from this point that knowledge becomes a force in cultural change. If ancestors hadn't cultivated technics as a field of knowledge, technological development would have been cut off before it began. We would still be Paleolithic. On the account I give in chapter 4, technology is a historical thing, an event in the history of technical culture. Human beings have relied on such culture in one form or another since the first stone tools. Chimpanzees could probably survive without their so-called tools, but for us, technical culture is a condition of existence. Imagine people like us in an African wilderness without clothes, knives, or fire! So there has always been technical culture. This culture is nature. "Technology" is not just another word for this ubiquitous

technical inheritance. Technology is a special configuration, a historical transformation of socio-technical economy.

With the Upper Paleolithic, humanity passes from an economy of artifice with little art or cultivated design (as in the Oldowan industry), to an economy of knowledge, for which the art these people brought to artifice (tools, sculpture, painting) is the strongest early signal. The next peak in the history of technics comes with agriculture, from about ten thousand years ago. The pace of technical advance quickens with the first cities and civilizations, from about five thousand years ago. Yet it was not until the Industrial Revolution in the 1770s and the nineteenth-century rise of engineering knowledge and polytechnical education that the socio-technical economy of, first, Great Britain, then Western Europe, America, and now the world, began to change. It began to become technological.

In the usage I follow, technology is an economic condition and a phenomenon of thresholds. It emerges in an economy when first some, then more, then most of what is made with tools and machines are other tools and machines, their parts, or accessories; when, consequently, most of what is made is designed to integrate, technically, with other artifacts. Machines are increasingly designed with other machines in mind, and may depend on complex networks of other machines and their parts. A Boeing 747 aircraft is a good example of fully developed technological artifice. It has 4.5 million parts. Its design required 75,000 engineering drawings.[81] The very being of this technological artifact presupposes innumerable layers of artifactual interaction, linking the plane to passengers, metallurgy, petrochemicals, telecommunications, engineering schools, and on and on. Without all these mediators it cannot fly.

We shouldn't make the mistake of believing the managers. That's when we look at a technology only after it comes on line, a dignified black box, with everything that betrays its contingency veiled by rational managers. Only those who have won the contests, survived the challenges, prevailed in the organization, believe that a technological system is "driven to the maximum yield at minimum cost." To anticipate my argument in the next chapter, there's nothing "purely technical" about any work of ours. Nothing about a technological entity has to be as it is. That is how little "calculation" is its essence and how fanciful the supposition that technology is driven by a rationality of "the one best way." Technological change is multicausal, path-dependent, serendipitous, opportunistic, and really contingent at its growing points, like the evolutionary speciation of a genus.[82] There is no telos, no essence, nothing to adumbrate in one-word-says-it-all terms like *das Ge-Stell* (Martin Heidegger) or *la Technique* (Jacques Ellul).

Our modern, advanced, scientific technology did not descend on the West as the benefaction of our enlightenment. Neither is it the ancient dream of metaphysics finally become terribly real. It is a late stage in the genealogy of some-

thing people have always done—enhancing options by artifactual facilitation, enhancing life through artifice and artifice through art. By the twenty-first century of our era we may have overdone it, or become dangerously thoughtless, but the human experiment with technology is not a fate from which only a god can save us. To save ourselves we require, not a new ontology, but a more effective appreciation of how things we do have unconsidered limitations and inconspicuous dangers we are not accustomed to account for. That is one reason I take a wide reading of "artifact" (chapter 2). Nothing in evolution prepares us to respond adaptively to antibiotic resistance or ozone depletion, yet these are precisely the sorts of consequences of artifice that should be recognized as artifacts too, and therefore as a necessary factor in technological design.

We describe people everywhere in terms of their tools and techniques—what they put together and how; and in terms of their aesthetic culture—how they enjoy and cultivate what is, in their eyes, beautifully put together. Humans share much else besides; for instance, the use of language and a genome we inherit from our common evolution. But what conclusion should we draw about art and technology? Are they adaptations, evolved and naturally selected behaviors promoting the survival of African ancestors? Probably not. We did not "evolve" to depend on art or technology, and remained unaccomplished far longer than since we began to advance artistically and technologically. The pursuit of technical performance, whether you call it *art* or *technology,* is an evolutionary afterthought, a latent potential developed long after natural selection made our organism as adapted as it was going to get.

That makes art and technology evolutionary spandrels—unselected by-products of natural selection that inadvertently became indispensable to human survival. The steady rise in brain volume is a constant of evolution in the *Homo* genus. Breeding ever bigger brains, natural selection eventually reached an organ whose unpredictable side-consequences and unselected by-products became at least as important to human survival as whatever brain function was being naturally selected, probably for language. Among these, though unemergent until late in prehistory, are the complementary capacities required for accomplishment in art and technology. It was something people had to *discover* they could do, and prefer and choose to do, well after evolution made it possible.

When people began to cultivate knowledge, the first thing they did with it was make works of art. In the time since then, artists and engineers have come to differ in media and ideology, though neither is *technical* or *artistic* in a way that excludes the other. Technical innovations grow from the same ground in art and technology—the anticipation of perception; off-line thinking about options; felt, aesthetic preference for a design alternative; and our ancient commitment to an ecology of cumulative artifice.

# 2. THE TECHNICAL



> Every manmade structure, no matter how mundane, has a little bit of a cathedral in it, since man cannot help but transcend himself as soon as he begins to design and construct.
>
> Samuel C. Florman, *The Existential Pleasures of Engineering*

The theory of tools and technical action is poorly developed in Western philosophy. There has been little advance over the ideas of Aristotle, which contain serious errors. Another source of misunderstanding is the "well-known fact" that lots of species use tools, especially chimpanzees. This chapter is partly a critique of prevailing ideas about tools and artifacts. I want to show the need for a new take on the basic concepts of technological civilization, including *artifact, artifice, technique,* and *tool.* One topic I will not be discussing is "modern" or advanced, scientific technology. I leave that to chapter 4. This chapter is about how technical cultures are alike. The history that gave the world our technological civilization is best told separately.

## Artifacts

> The flood of consequences following on artifacts has so far not been a central concern of passionate philosophical inquiry.
>
> Ivan Illich

Most conceptions of an artifact understand it to be a purposive thing, which is a half-truth that becomes a serious mistake when purpose is understood as Aristotle

and Kant did—as causation by an idea. The idea becomes the antecedent form, the essence of the artifact, its final, teleological cause. The difficulty for this theory is that the unintended consequences of artifacts are artifacts too. Smog, trash, and an ozone hole are nobody's purposes, yet they are artifacts because they are the effects of artifacts, and anything that would not exist were it not for artifacts is an artifact.[1]

When we describe artifice in terms of an intended, purposive result, we describe an artifact ("What are they making?" "Automobiles"). When we describe an unintended consequence or a counterpurposive by-product, we are *redescribing the same action* in these alternative terms. To describe technical action in terms of purpose or goal (for instance, manufacturing cars) is one of many true descriptions of the action on a factory floor. Descriptions in terms of unforeseen consequences (making smog), or indifferent by-products (making a lot of noise), are equally true of the action, equally *what is done,* equally the description of an artifact.[2]

What seems to me important about the idea of artifact, what gives it sense in thinking about art and technology, is that it comes to be through artifice, individual or concerted. What artifice makes is an artifact because artifice makes it, not because of the description it falls under. In technical terms, artifactuality is an extensional, *de re* property of events and their effects, not an intensional, *de dicto* attribution. It depends on our act, its happening, not the descriptions that may fall under. If one effect of artifice is "made" (is artificial or an artifact), so are they all. The purposive form is as "made," as "artificial," as the unintended, counterpurposive by-product.

Consider for example the relationship between the manufacture of chlorofluorocarbons (CFCs) and the ozone hole, a paradoxically counterproductive consequence of their use. Their advocate, American chemist Thomas Midgley (his two inventions of CFCs and leaded gasoline made the greatest impact on the atmosphere since cyanobacteria poisoned the air with their effluent oxygen), would blow a lungful of the stuff over a flame, proving it both safe to breathe and nonflammable. What he didn't know is that it catalyzes a process decomposing atmospheric ozone. Being inert, the stuff accumulates high in the atmosphere, and as a catalyst it is not used up in reaction with the ozone. The elegant mechanism by which chlorine atoms are liberated from the CFC molecule and transported by ice and dust particles into the ozone layer looks as if it were carefully engineered to do something nobody wants to do—cheaply and effectively remove vast quantities of ozone from the Earth's atmosphere.[3] CFCs are artifacts—purposive, designed, used. An ozone hole is an artifact—counterpurposive, undesigned, useless. The hole *is* the use of CFCs under another description. One thing we did when we made and used them is make an ozone hole. The hole would not exist apart from the artifice and is therefore an artifact.

What then shall we say an artifact is? I say an artifact is an effect of human performance, individual or concerted, under any description. The reference to humans excludes, for instance, chimpanzees, for a reason I'll explain. The reference to performance is required because artifice is not the seeming purposiveness of adaptive behavior, a quality artifacts share with beaver dams. Artifice is more than adaptive behavior; it is *performance,* which implies normative accomplishment rather than an instinctive, species-specific behavior and its adaptive effects, like a beaver dam. Finally, as it is these actions that produce artifacts, any of their descriptions, including descriptions in terms of unintended or counterpurposive effects, describe artifacts.

Perhaps this understanding of artifact lacks the spontaneous acclaim of common sense, but the departure seems justified, and not so different from conclusions reached by others who have tried to think about artifacts. Archaeologist Michael Brian Schiffer defines artifacts as "phenomena produced, replicated, or otherwise brought wholly or partly to their present form through human means."[4] Although he doesn't make this explicit, counterproductive consequences like smog equally come into being "through human means" ("wholly or partly"). Had we not exercised our means, engaged in artifice, organized concerted technical action, the counterpurposive consequences would not have existed. What more does it take to make something something we make—and what else is an artifact?

Extending the denotation of "artifact" to all the effects of artifice more closely matches the human impact on our ecology. It's important to understand that *what we bring about,* our artifacts, include counterproductive consequences, because such consequences are failures (or limitations) of art and knowledge. The arts of artifice, the *ars* or *techne* of any art or technology, flourish on the interface of knowledge and deliberate, purposive control. Counterpurposive effects are artifacts of *the failures and limitations* of design knowledge. Acknowledging these consequences as failures of knowledge emphasizes our complicity in the artifacts of technological civilization, and the need to know better what we do not know.

I want to develop this point about effects of artifacts being artifacts, because it helps to understand what design adds to artifice. There are unintended, unforeseen consequences of artifice only because there are intended, foreseen consequences. Not every artifact has purposive form (smog, ozone hole), but unless there were purposive artifacts, these purposeless ones would not exist. Although unforeseen consequences are artifacts, the event of which they are consequences must admit of intentional, purposive description, referring to an effect that shows design and technique. Let me call the artifact as intended, planned, designed, and executed a *work*.

What distinguishes a work from the side-effects or by-products of its artifice is its artfulness, its technical coherence, well-made parts in a well-designed system.

Cars are works while smog, equally an artifact, is not, because cars are technically coherent in a way that the counterproductive smog is not. Not only are automobiles highly planned and deeply purposive; they are crucial to the coherence (such as it is) of a global economy of other artifacts—highway construction, metallurgic research, trade union politics, the economies of cities, the geopolitics of oil, and so on. By contrast, smog is incoherent with the motives that generate it, the economy that externalizes it, and the environment it degrades.

Technical coherence is relative to a level of description and analysis. The coherence of cars fades into blatant incoherence as we expand the economic horizon and calculate the cost of ecological degradation visible only from the long-term perspective economists avoid. The polystyrene box in which burgers are served in their billions is all too coherent in a technical sense, holding up all too well and standing out all too plainly as an artifact. In this case the technical coherence of the work *enhances* the ecological incoherence of a frivolous commodity whose incidental utility produces garbage orders of magnitude more lasting.

Technical coherence, which can be explained as the artfulness of artifacts all things considered, is the quality I suggest we have in mind when we speak of design. Departures from coherence, the descent into incoherence, for example in unexpected counterproductivities, is equally a defect of design, a problem or limitation, a point at which design knowledge fails to be as good as it might. The appearance of design in organisms, where organs (heart, liver, and so on) seem to be "for" particular functions, and relations among species (for instance, bees and flowers) seem purposive, is, as Kant said, "merely formal." The appearance of design belongs to the form of our understanding, not to a thing in itself. What (in Kant's language) is "formally purposive" merely *seems* purposive, has *the look* of purpose, *appearing* designed.[5] There's a difference between looking designed and being so. A jet aircraft is designed and looks that way. The body of a bird *looks* designed, *seems* purposive, although it is neither, being a mechanical outcome of mindless evolutionary causes, especially natural selection, operating over geological time.

The "design" in nature (the appearance of design) is "merely formal," an artifact of our understanding. Kant thought that we *have* to understand nature that way, that it's a transcendental condition of rationality. I am more impressed by the sheer contingency of the thing. It seems to me unlikely that we would perceive seeming or merely formal design in nature without the experience of actual design in the work of our hands. We know the far-reaching effects of writing on cognition.[6] Those of artifice must be more basic still to human mentality. Having long surrounded ourselves with our own constructions, we look on practically anything as organized, purposive, even when we have no idea who made it or for what. We look on what are not works as if they were, and analyze their "mech-

anism." Inhuman things (landscapes, flowers, sunsets) appeal to us, and we respond as if they had technical qualities only works bring into the world—coherence, form, artifice, design.

It must have been works—things that make sense because of how they are put together—that inspired Western thought with the idea of "the way the world is," an ultimate synthetic order that is "finished" and makes sense as a structure. Belief in this Ultimate Architecture is as naive as thinking the sky is blue. Blue comes from us, our perception. Coherence also comes from us, from our penchant for putting things together in ways that work. Remove our yearning for making sense and no residual coherence remains among things in themselves. The anticipation of the object is an artifact of artifice. The difference between what I'm saying and Kant is that coherence and design are not "purely imaginary" qualities. They are real, *worked* qualities of a work, material in the first instance.

Of course artifacts have to be made of something, and they are—other artifacts. The reference from artifact to artifact is endless, not in the impossible sense of a world resting on the back of turtles that go all the way down. The endlessness is that of any economy. Where there is one coin or banknote there are always more. Move from one to the next, you never come to the end of them. Same for the words of language, or kin, or gifts. There is always more than you can account for, even though every extension of the accounting only uncovers more of the same.

It is usual to contrast artifact and nature, though this distinction becomes tenuous once we take on my enlarged sense of artifact. What if anything is nature or natural depends on how we understand "nature." If it means a green place with birds, then nothing has changed. If it has the technical meaning of Aristotle, where *phusis* is the first, primordially given order, settled in substances of eternal form and essence, then I'm afraid the idea of "nature" is long discredited. The conclusions of the sciences have run against it ever since Darwin, Einstein, and Bohr, when the universe lost finality, substance, and eternity, becoming stochastic and evolutionary. Finally, if "nature" means the original and untouched, an order of being prior to all artifice, this too must elude us. It's just another name for the inscrutable "thing in itself." We have no right to assume the reality of anything so inhuman. To confirm its existence would require a prodigious work of purification, mobilizing legions of laboratories and far-flung centers of calculation, all of which would make the purest "nature" (supposing we found it) the most heterogeneous hybrid, an artifact of socio-technical economy, subverting its inhuman claim to inhuman objectivity.[7]

Is there then nothing that isn't an artifact? How can that be? Human beings are a geologically recent irritation on the planet surface, a planet that will spin lonely eons after we're gone. How can the earth, the stars, atoms of hydrogen in

distant galaxies—how can all that be "artifacts"? Because they're our conceptions, because we think them up, because they are symbolic constructions, which certainly have their value—they can even be true—but do not correspond with "things in themselves." As far as human thought and practice go, it's artifacts all the way down, a point peerlessly expressed by Nietzsche in a passage addressed "To the realists":

> You call yourselves realists and hint that the world really is the way that it appears to you. . . . That mountain there! That cloud there! What is "real" in that? Subtract the phantasm and every human contribution from it, my sober friends! If you can! If you can forget your descent, your past, your training—all of your humanity and animality.[8]

## *Logos* and *Techne*

The interpretation of technical action in classical Western thought introduced a number of assumptions still current in modern behavioral sciences. Aristotle thought of an artifact (*ergon*) as the *telos* of *techne,* which he explains as what craft brings forth in accordance with a *logos.* He says that *techne* "consists in the conception of the result to be produced before its realization in the material." The actual making is mechanical, a laborious execution of the idea's program, like a template for tracing artifactual form on raw material. The rational soul uses the body as the body uses a tool. "The saw is made for sawing. . . . Similarly, the body too must somehow or other be made for the soul."[9] The artisan's *techne,* his or her skill, craft, art, or knowledge, is the *logos,* the rationality, that guides the laboring body. Idea comes first; the artifact is secondary. Knowledge begins in the soul, guides the hands, and finally informs the material of an artifact.

Most of the textual evidence for this conception comes from Aristotle, though Plato does say that craftsmen (*demiourgoi*) "apply their measures not at random but selecting them in order to get the thing they are making to acquire a particular form (*eidos*)." A commentator explains that "the craftsman aims to inform the material upon which he works, and everything he does is guided by what he 'keeps his eye on,' namely, the model or preconception he plans to actualize . . . the determinate form dictating where and how [parts] fit." In *Timaeus* Plato writes that "whenever the craftsman looks at what is always changeless and, using a thing of that kind as his model, reproduces its form and character, then, of necessity, all that he so completes is beautiful. But were he to look at a thing that has come to be and use as his model something that has been begotten [that is, another artifact], the work will lack beauty."[10]

In many dialogues the artisan or master of *techne* is Plato's model of knowledge. But what is the upshot of these discussions? What does he seem to learn from his interrogation of *techne?* Precisely that the best and highest knowledge (*episteme*) cannot be a *techne!* One reason is that *techne* aims at concrete results, producing a ship, a healthy person, a drama, and so on. The best, most philosophical knowledge can't concern itself with anything so mundane. Its objects are the eternal Forms in which all particulars participate. There is no way for *techne* to produce something eternal. To produce is to initiate, to create, while Truth is uncreated and timeless. A second reason is that *techne* can be used for good or ill. Such knowledge is instrumental, serving other ends, and its effectiveness is no guarantee that the ends are good. But the best and highest knowledge is knowing in the light of the Good itself. Ultimately, there is no difference between knowing Truth and knowing the Good. Such knowledge cannot be a productive *techne* that might as well be used for bad. This understanding of knowledge (or the best, most philosophical knowledge) passed practically without comment from antiquity to modern times. Among critics Nietzsche was first, though William James independently arrived at similar ideas.

Aristotle defines *techne* as "a state of capacity to make (*poitike*), involving a true course of reasoning (*logos*)." He says that *techne* "consists in the conception of the result to be produced before its realization in the material." "The things that come to be by *techne* are those whose form is in the producer's soul." "The *logos* forms the starting point, alike in works of art and in works of nature." How does the physician or builder set about their work? "He starts by forming for himself a definite picture . . . of his end—the physician of health, the builder of a house—and this he holds forward as the reason and explanation of each subsequent step that he takes."[11] Medieval philosophers confirmed Aristotle's ideas when they thought about *ars,* their Latin translation of *techne.* For Thomas Aquinas, "art is nothing but the right reason about certain works to be made (*factibilis*)"—the "one best way," according to *logos.* For his thirteenth-century contemporary Bonaventure, "The work of art proceeds from the artificer according to a model existing in his mind; this pattern or model the artificer studies carefully before he produces and then he produces as he has predetermined. The artificer, moreover, produces an exterior work bearing the closest possible resemblance to the interior model."[12]

Modern philosophers remained Aristotelean on this point. Auguste Comte considered the Aristotelean analysis an "elementary truth" with important implications for social order. "Each entire human operation, from the simplest to the most complicated, whether executed by an individual or by a multitude, is unavoidably composed of two portions . . . one concerning the conception, another the execution. The former, of necessity, preceded the later, which it is

destined to guide."[13] Even Karl Marx didn't question the theory. His concept of production is a homage to Aristotle:

> We presuppose labour in a form that stamps it as exclusively human. A spider conducts operations that resemble those of a weaver, and a bee puts to shame many an architect in the construction of her cells. But what distinguishes the worst architect from the best of bees is this, that the architect raises his structure in imagination before he erects it in reality. At the end of every labour-process, we get a result that already existed in the imagination of the labourer at its commencement. He not only effects a change of form in the material on which he works, but he also realizes a purpose of his own that gives the law to his modus operandi, and to which he must subordinate his will.[14]

R. G. Collingwood strongly reaffirms the classical thinking, the better to distinguish *techne*-craft from what he thinks is properly called a work of art. He defines *techne* as "the power to produce a preconceived result by means of consciously controlled and directed action." He emphasizes preconception: "The result to be obtained is preconceived or thought out before being arrived at. The craftsman knows what he wants to make before he makes it. This foreknowledge is absolutely indispensable to craft. . . . The end is thought out first, and afterwards the means are thought out."[15]

For Collingwood, that proves the difference between the act of imagination, which creates art, and the mechanical, merely technical routines of the craft that brings artifacts (including paintings and so on) into existence. He says making an artifact "consists of two stages. (1) Making a plan, which is creating. (2) Imposing that plan on certain matter, which is fabricating."[16] The creativity is over before the work is started. As Ernst Cassirer observes, "the whole constructive process, which is a prerequisite both of the production and of the contemplation of the work of art, is entirely overlooked." A commentator makes a similar point about Aristotle: "We do not get any sense of a making that is itself intelligent, endowed with a know-how which is learned and materialized in the very process of making. The intelligibility of making seems to be fully constituted by a thought process which is independent of the process of making."[17]

The Aristotelean idea of *techne* readily adapted to a Romantic conception of art as the antithetical artifact, everything *techne* is not. The Romantic assumption is still defended in critical theory and cultural studies when, for instance, Aristotle is anonymously and probably unknowingly invoked to define the essence of technology: "In technology, the object's actual production is preceded by a rational, end-oriented blueprint." Then comes a Kantian and Romantic moment, distinguishing the pure object of art from the preconceived works of technology, as Collingwood did: "Insofar as the work of art produces its own concept rather

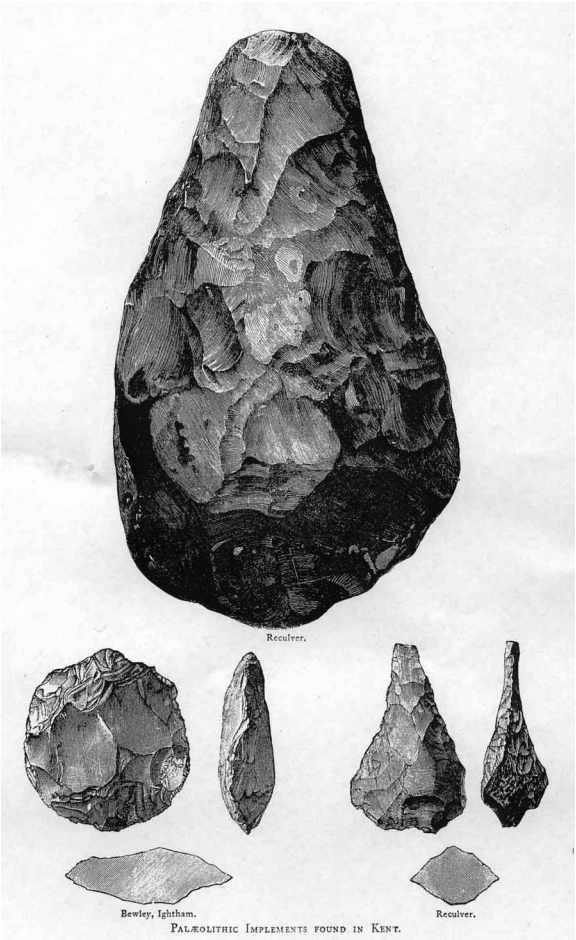


**Figure 2.1** Acheulian Stone Tools. Tools of this form were first made in Africa about 1.5 million years ago. Illustration from *Victoria County History of Kent,* vol. 1 (London, 1912), 312.

than deriving it from a blueprint or preset idea, it is unprecedented. This *shock* inherent in any work of art is crucial to its understanding. Without this inaugural character, the artwork would not be essentially distinct from other forms of human production ruled by skill, craft, that is, technology."[18]

The ancient analysis lives on in anthropology and archaeology, too; for instance, in the idea that that stone tool making involves a "mental template," an immaterial instruction (*logos*) that prefigures the material artifact and guides the body. Consider

archaeologist Keith Oakley's explanation of an interesting archaeological find. Acheulian hand-axes (figure 2.1) are found with a high degree of standardization in material as different as flint, sandstone, quartz, and lava, at sites from the African Cape to England, over a period of hundreds of thousands of years. How can they be made so similar for so long without drifting into new shapes? Oakley explains, "Men who made tools of standard type must have formed images in their minds of the ends to which they labored." Decades later, prominent paleoanthropologists can't improve on the theory. "Unlike the Oldowan artifacts [figure 2.2], which show no definite preconceived shape that their makers were trying to produce, these Acheulian tools show unequivocally that these hominids had specific mental templates of the forms they wanted." "The stone tool maker is guided by a series of mental images of shapes which already exist in his mind (concepts, templates)," says another authority. "At each [stage] the real situation is compared with the underlying mental image of the ideal next stage."[19]

Talk of mental templates governing artifactual form explains nothing. It does not help to explain the genesis of artifactual form to say that the form was always there anyway, in a different state of being, immaterial, an idea, supervising its own materialization. The only evidence of the hypothetical mental template is the artifact we are trying to explain, and there is no way to identify the template except by referring to it as something with the effect we are trying to explain, which makes it like the "dormative virtue" explanation of opium. Technically, a template is a jig, which is not a good metaphor for cognition or its role in artifice. A template, like a map or plan, is a device, a tool. Such things *require* knowledge to exist or be used, which makes them poor models for the cognition that underlies the accomplishment of knowledge. If technical action requires mental templates, then it takes a template to use a template, and technics becomes the inexplicable machination of homunculi.

What makes the mental template picture plausible may be the impression that artisanal production is mechanical or routine, as if the rational, mental part of the craftsman had read the plans, and moved his body as a hand moves a tool. Such a view betrays the usual error of nonpractitioners trying to comprehend technical action beyond their experience. To contemplative lookers-on, artifice may appear effortless, even mechanical, but only because of what they cannot see, like alternatives considered and rejected, risky transitions in form or operation, and split-second choices to compensate for unforeseen developments. Only a spectator innocent of artifice would think artifactual form imitates something immaterial and preconceived. The art of artifice is not the reproduction but the reinvention of form.[20]

The contemplative perspective logically leads to the view that the better *techne* gets, the more automatic, predetermined, certain, the outcome. Hence Aristotle's

inference that "those occupations are most truly *technai* in which there is the least element of chance."[21] Presumably the thought is that as *techne* becomes truer, artifactual form is so well articulated, *logos* so in command, as to make execution purely mechanical, that is, risk-free. This is an early formulation of the idea that the step from plan or design-concept to artifact can be "purely technical," meaning mechanical, machine-programmable, capable of risk-free execution by technically rational agency—what Thomas Aquinas called "right reason." This notion of technical rationality, with its ideas of efficiency and "the one best way," derives, fallacies and all, from the contemplative bias of classical Western philosophy.

I propose two corrections to the contemplative account of artifice. First, no idea, plan, concept, or *logos* causes artifactual form. Second, technically coherent design is never determined, necessitated, or rationally implied by anything beyond the choice of the designer, least of all by an impersonal, objective rationality of function.

To begin with the first point, a plan or design-idea stands to actual artifice as a score to a musical performance, whose quality depends on more than a good composition. In music as in all the arts, everything ultimately depends on the craftsmanship, workmanship, or (as I prefer) *artifice* of those who complete the design. The contribution of artifice is unique and cannot be mechanized or reduced to an explicit instruction. A lot of modern engineering is dedicated to eliminating the need (and risk) of skilled artifice, devising ways to do without it by automated, mechanically determined systems. An automated machine can now make practically any shape skill can make, though not always economically. Yet we are as far as ever from overcoming technology's reliance on skillful artifice. As a scholar of technics observes, "as fast as machines have been contrived to do what had previously been done by skilled hands, different skills have sprung up for the handling of the machines themselves." The history of technics "might be interpreted as a constantly renewed attempt to build skills into machines by means of algorithms, an attempt constantly foiled because other skills always tend to develop around the new machines."[22]

Discussing hands in chapter 1, I mentioned that no two actions are performed exactly the same way. That is especially true of technically skilled action, where the algorithm, "motor program" picture seems dead wrong. Technical skill cannot be (entirely) mechanized or (entirely) replaced by mechanisms, nor can the risk inherent in technology's reliance on artistry be eliminated. Obviously design depends on artifice for a work's appearance and functionality. Design has no content, no idea, no knowledge of what materials there are or what can be made of them apart from what artifice has accomplished. There is always more to an artifact than design. Artifice makes an irreducible contribution to appearance and performance.

My second point is that there's nothing uniquely rational, functional, or efficient about even the best-designed artifacts. No norm of rationality, no physics of efficiency, no *logos* or right reason necessitates the (rational, functional, efficient) design of any work. David Pye, an architect, industrial designer, and Professor of Design at London's Royal College of Art, is the most technically accomplished philosopher of design since William Morris. He makes a point that deserves the attention of every philosopher of technology:

> When any useful thing is designed the shape of it is in no way imposed on the designer, or determined by any influence outside him, or entailed. His freedom in choosing the shape is a limited freedom, it is true, but there are no limitations so close as to relieve him or the maker of responsibility for the appearance of whatever they have done. The ability of our devices to "work" and get results depends much less exactly on their shape than we are apt to think. The limitations arise only in small part from the physical nature of the world, but in a very large measure from considerations of economy and of style. Both are matters purely of choice. *All the works of man look as they do from his choice, and not from necessity.*[23]

Technical cultures or technological systems differ because there is always more than one skillful, technically appropriate way to do anything technical. This is obvious in art. We are not surprised that one people's art is different (differently put together) from another's. We would be surprised if it weren't! Apparently it's more difficult to think of technology that way. Jürgen Habermas calls technology "an objective system of relations among things, that is wholly exterior to the social domain of relations among persons." Tools and techniques are governed by norms of the "purposive-rational utilization of means." Jean-François Lyotard, though usually Habermas's critic, shares this picture of technical reason. "Technical devices . . . follow a principle, and it is the principle of optimal performance: maximizing output . . . and minimizing input. . . . Technology is therefore a game . . . [of] efficiency: a technical 'move' is 'good' when it does better and/or expends less energy than another."[24]

Anthropologist Edmund Leach divides societies into technical systems and social systems. Only social relations are properly "cultural." Technics is merely practical rationality discovering how things work. The social sphere is the semiotic, ruled by arbitrary signs and conventions. That's where the culture is. The technical system, which pits instrumental rationality against the forces of nature, produces its results "in a strictly mechanical way."[25] This dichotomy between culture and technics assumes there is a "purely technical" level at which the choice of material, techniques of fabrication, finished form, or mechanical operation are determined by the "physics" of the assembly, with an objective finality that can be intellectually perceived. Technical action (to this way of thinking) is a pragmatic,

efficient, optimal, and in that sense rational, even uniquely rational, response (what *any* rational being would do) to mechanical necessity, physical inevitability, means and ends, the "laws of nature."

This idea of technical rationality has drawn criticism in several fields, including the critical theory of technology, anthropology, archaeology, and science studies. The gist of the discontent is that how we make and what we make do not express a rationality independent of local context. Technics is social action, according to archaeologist Marcia-Anne Dobres. "Clay pots do not 'need' to be made in a certain way any more than blade production 'requires' prepared platforms of one sort or another. Those performance needs, those fabricative and use requirements (or production standards) rest with the makers and users."[26] For philosopher Andrew Feenberg, "pure technical principles do not define actual technologies. They must be concretized through a technically realized conception of the good which particularizes them and establishes them systematically in the life process of a society." Choice among technological alternatives "ultimately depends neither on technical nor economic efficiency, but on the 'fit' between devices and the interests and beliefs of the various social groups that influence the design process."[27]

Nothing is made as it is because only that way works. Anthropologist Pierre Lemonnier shows how readily that's confirmed once we accept the possibility and look for the evidence. He draws on fieldwork with the Anga people of New Guinea, where he first encountered the "strange phenomenon," as he describes it, of *technological arbitrariness.* He found technical operations that are known and known to work, yet are not taken up but rejected. For instance, Anga men know three ways to build a pig trap, each with an entirely different mechanism. The men of the scattered communities know of each trap and can even sketch them, though all have their local norm and never use the others.

This strikes Lemonnier as irrational. "A perfectly understood technology is voluntarily ignored." He found groups familiar with barbed arrows of supposedly superior performance than those they use. Their determination to use one form and not the other is "proof that *a reason other than 'technique'"* opposes "the adoption of a device clearly more deadly than the ones they habitually use."[28] Different communities among these people build their houses on one of two plans. Methodical musing revealed no correlation with environmental differences. For no good technical reason, villages just hours or days away build houses to one design rather than another, and more is involved than technically indifferent ornament. The differences concern the engineering of the structure. Local experts insist their way is right, that any other would be, as it were, bad engineering, yet the form they prefer is arbitrary relative to functionality. It could have been put together quite differently and worked just as well.

Lemonnier finds his evidence "strange" and "quite surprising." He seems to regard a view like that of Leach or Habermas, which sees technology as external, objective, and rational, as the default assumption among anthropologists. The conclusion he draws is that human beings cannot get involved in anything however rational without bringing arbitrary social representations with them. "The physical and informational dimensions of technology are embedded in each other, simply because societies are always manipulating symbols whether in designing airplanes or in rocking babies."[29] I interpret the evidence differently. I think we should expect precisely what Lemonnier finds, and not regard it as strange or surprising. What he calls "the physical aspects of action on matter" so radically underdetermine technical form (how a device is put together) that it is inevitably in some respects arbitrary relative to intended results. Anything we make could have been made other ways. The "one best way" simply does not exist.

The problem of technically coherent design is not to find this mythical paragon of efficiency but to eliminate technically feasible alternatives, whether because of cost or because of style, aesthetics, look and feel. "Style" originally referred to choice and combination of words in writing, but choice and combination are what design is all about. Naval architect J. E. Gordon compares ship design to "the exact and loving placing of words in writing." It "differs from the creation of poetry only in its numerate content."[30] Every work has its style, whether it is mass-produced (a jar) or handmade (a carpet), aesthetic (a painting) or structural (a bridge). The reason is because anything *made to work* is always at the same time *a work,* and there is more to any device than intended use dictates, including work on appearance.

The qualities Lemonnier calls arbitrary belong to technical artifacts as works rather than as working, as made rather than functional, as finished artifacts rather than tools in use. To work, a technical form has to do more than work, and has to have qualities acquired not because of how it works, but by the artifice that brought it into existence. Style is deeply implicated in all our works because the use or function of artifice never determines shape or form. To call the contribution of style an intrusion of the arbitrary implies that it is a matter of indifference, that alternatives would have been "just as good." Yet the goodness of design is not measured by disinterested instrumental rationality (which is a myth) but relative to a tradition of comparable work. By that standard it is obviously not true that technically possible alternatives are as good or work as well. They may look all wrong, and that's a way of *being* wrong, even in engineering.

I can imagine a reader who at this point might say: Granted, there's an exaggerated tendency in Western theory to treat artifice as preconceived and understand preconception as the contemplation of a template; granted, these ideas face serious difficulties, especially in understanding the arts; yet a lot of practical action

and technical production clearly requires some anticipation or preconception. One needn't consult extreme cases of the thousands of drawings necessary to produce an airliner to see that. Obviously artists and artisans muse, mull, entertain, and ponder as they think their work though. Isn't that the "off-line thinking" I discussed in the last chapter? What is that, if not imagining the finished form? What's the difference between off-line musing about form and a mental template?

A preconception prior to commencing artifice is presumably a matter of experience, which teaches what can be done, allowing one to anticipate making a thing similar to (or differing from) a thing one has made before. What exactly experience contributes, how it makes the difference it does, allowing for increasingly detailed and inventive control of artifice—that I do not know. Does anyone? It seems likely that experience is a condition of accomplishment in artifice, whether in engineering or sculpture or weekend carpentry. It seems unlikely that artifice involves the contemplation of a fully present form or template. Off-line musing means thinking about the products of cognition; for instance, thinking about how something looks, thinking about a purpose in making a thing, anticipating the effect one seeks, and identifying (in thought) obstacles to its realization. I'm sure an articulate artisan could add to these superficial observations, but they confirm that the preconceptual cognition of artifice is not satisfied with the already finished presence of an immaterial form.

## Chimpanzee Tools

While the claim that chimpanzees can learn to use language drew skepticism from the start, researchers accepted the claim that they use tools without contention. It's obvious. Jane Goodall says that the first time she saw a chimpanzee fishing for termites with a twig "it was obvious that he was actually using a grass stem as a tool." Our tools are more complicated, of course, but as an anthropologist cautions, "they are *not fundamentally different* from those used by chimpanzees. Both are, when described in a broad and basic way, physical objects used to obtain an end." Another spokesman for the chimpanzees says it is "pretty clear that apes . . . can indeed make and use tools—cruddy tools to be sure, but tools by anyone's definition."[31]

Not mine. I ask myself, what concept of tool is complicit with this obviousness? What are people seeing in chimpanzees that makes them think, *Ah ha! she's using a tool!*? When you read the scientific literature with this question in mind, you discover that chimpanzee tools are not the only primitive behavior on display.[32] Considering the credulous reception it seems worthwhile, if only for the experiment, to press the case for skepticism as hard as I can.

Skepticism about chimpanzee tools is not skepticism about evolution or evolutionary continuity. I take for granted the genealogical continuity of human beings and other species, especially mammals, particularly primates, above all chimpanzees. My argument is that no evolutionary lineage leads, by continuous mutation, from chimpanzee-like apes with chimpanzee-like tools to modern humans and human tools. The two lineages diverged and underwent separate vicissitudes since our last common ancestor. Stone tools first appear with *Homo,* well after the hominid/pongid split.[33] The use of tools is a *difference,* not a similarity, between *Homo* and *Pan.* That's my argument in a nutshell. Now let me discuss the evidence.

As many as twenty nonprimate species are supposed to use tools, including otters, wasps, and several species of birds. However, chimpanzees (*Pan troglodytes*) are the most important case, from which we supposedly learn the most about ourselves and our tools. After all, we're 98 percent genetically identical! Chimpanzees are said to offer "a glimpse of what the primeval stages of culture may have been like in our own evolutionary past." These animals "are not merely fellow time-travelers and evolutionary relatives, but surprisingly excellent models of our distant ancestors." Data on chimpanzee tool use is said to have "broad implications for our understanding of the ecological and cultural factors that shape hominid tool use," presumably because these animals are "the best nonhuman species available for modeling the tool-use of our ancestors" and "the best available source of knowledge about our behavioral evolutionary past."[34]

Probably the most exciting thing about chimpanzees is that their various tool-using behaviors are not a species-specific inheritance. Tool use is peculiar to isolated groups in a way that seems analogous to culture. Every *Cactospiza* finch uses a twig or cactus spine to dig insects from trees. All select a similar "tool" and reject anything too short or flexible. Nothing like that for chimpanzees. Their tools run from stone nutcrackers, to lures for fishing insects, and include the use of levers, probes, sponges, medicinal plants, and the daily construction of an arboreal nest. Yet there is no one tool they all use and every population has a different kit. The use of stones to crack nuts, for instance, is not always found, not even where there are stones and nuts.[35]

The "tools" of species like wasps and birds, with whom we have not had a common ancestor in a very long time, are likely to be a separate evolution, hence thin analogies to humanity. To be less inconsequential the chimpanzee behavior has to be not *like* human tool use, not an analogy (there's lots of those), but an evolutionary homology. Homology is the genealogical relation between characters of two or more species derived from their last common ancestor.[36] A well-studied example shows how the anterior extremity of a common mammalian ancestor gave rise to a series of homologous structures modified for digging (moles), grasp-

ing (monkeys), swimming (whales), and flying (bats). Homologies exist not only in structure but in any heritable trait, including behavior. So "tool use" could, theoretically, be homologous in chimpanzees and humans. Except that a character homologous in humans and chimpanzees has to be inherited by all the descendants of the common ancestor, and that includes gorillas and bonobos, neither of which use tools in the wild. That precludes the homology of chimpanzee and human tool use. There is no descent for this trait from a common ancestor.[37]

Louis Leakey thought Goodall's observation of chimpanzee tools refuted Benjamin Franklin's definition of humanity as the tool-making animal.[38] Technically, only a true homology would refute that, and chimpanzees aren't it. They are dexterous and clever, but seem to have little manual skill. It reportedly takes a chimpanzee ten years to master the trick of cracking nuts with a stone. Kanzi, a bonobo prodigy, was taught to knock off stone flakes to cut a rope and get a treat. Despite the best effort of a team at Yerkes Primate Research Laboratory, his skill remained below that of the most primitive hominid tools. Kanzi is an incorrigible basher, with no idea of a controlled, forceful blow at a precise angle, a quality prominent in the first stone tools (figure 2.2).[39]

Gorillas are as closely related to chimpanzees as chimpanzees are to us. Among apes their hands combine the longest thumb with the shortest fingers, giving them superior opposability, though they make and use no tools.[40] I mentioned (chapter 1) that a chimpanzee's hand is not much like that of hominids, especially modern humans. The plan of our hand stayed closer to the unspecialized five-ray forepaw of early vertebrates, retaining the primitive pattern and forgoing the anatomical specialization apes developed for brachiation. Australopithecines, who possessed a hand more hominid than pongid yet made no stone tools, remind us that the conditions of manual skill are in the head as much as in the hand.

Just because chimpanzees happen to be our closest evolutionary kin among contemporary species doesn't mean they can acquire the use of language, a claim on which, it seems to me, the jury is still out. Neither does it mean that the analogies between their behavior and the human use of tools are close or instructive. There was a lot of evolution, a lot of differentiation, in the 250,000 or so generations that separate *sapiens* and *Pan*. The editors of an authoritative research survey conclude that "the evolutionary evidence supports the view that human and chimpanzee behavioral traditions are only analogous. The social-cognitive adaptations on which human culture and cultural learning depend came only after the differentiation of the two species."[41]

*Only analogous.* Of course no analogy is perfect and not all are illuminating. Some can be downright misleading; for instance, the analogy of flight in birds and insects. The value of an analogy has to be weighed against misleading disanalogies. These countervailing differences are so little considered in the

"chimpanzee tool" research that I am going to take a few pages to summarize what I've gathered from the literature. You don't get human tools by starting where the chimpanzees are and then just getting "more complicated." That's the wrong geometry, which has to be not two- but four-dimensional, representing differences of ecology, society, technical economy, and aesthetics.

### *Ecology*

Tool use costs chimpanzees little, adding little or nothing to the exigency of reproducing their species. Despite taking sometimes significant seasonal food from termites or nuts (at the Gombe reserve in Tanzania, termites are the fifth most common item in the female diet), their so-called tool use seems incidental or secondary. Magic away rocks for hammers or sticks for insect-dipping, and I have the impression they would not be direly missed—not like antelope without grass or people without fire and blades. Tools belong to the ecology of our evolved form of life in a way without parallel in *Pan*. It was probably crucial to the survival of the incipient *Homo* line to hunt small animals or scavenge for meat and marrow, which is impossible without stone tools. Chimpanzees, on the other hand, descend from primates that remained largely vegetarian and retreated with receding tropical forests into the central African regions where they still are.

While the early *Homo* diet was no doubt largely fruit and vegetable, these ancestors were not specialized for such food, as later australopithecines were. *Homo* species probably took meat often, and for that stone tools are not merely convenient but indispensable. These early *Homo* species had no bone-crushing jaws to extract fat-rich marrow, nor the teeth or claws to get meat under a hide. With nails in place of claws, reduced canine teeth, a delicate jaw, and a serious need for protein, early *Homo* species were unviable without stone tools. The use of fire is important too. One can only digest so much raw meat. Fire greatly improves meat's food efficiency. We can eat more of it and digest and use it more effectively. Dating the control of fire remains controversial, so it is unknown whether the first hominids to use stone tools had also mastered fire.[42] Yet stone blades are of severely limited value without fire, just as experiments with fire are of little value without blades and the meat they make available. Together, though, stone tools and fire create a mutually reinforcing economy of very high survival value.

The ecological dimension of tool use has been overlooked by historians of technology as well as primatologists. The author of a well-regarded work on the evolution of technology writes, "Animals exist and thrive without fire or the simplest shaped stone utensils. Insofar as we are animals, on the zoological plane of existence, we too could live without them." A philosopher of ecology takes the same view of technics: "It is simply human, not techno-human beings who belong in

natural systems, as claims about an ecological niche can only be made for an animal in its natural state."[43] Techno-humanity *is* our natural (that is, evolved) state. There is no "zoological plane" on which human beings exist in technical innocence, no moment before we ate from the tree of technics. Take away tools and you don't have the naked human animal on a purely natural plane of existence; you have an ecologically imperiled species rapidly heading for extinction. Technical culture *is* our zoological level of existence, technics an existential presupposition of *Homo sapiens,* as much as fresh water. Unlike chimpanzees we are born to the tool. Apart from it our adaptation falters and fails. We have evolved a neurology unique in the history of life for being unviable apart from a fabric of artifacts, tools first among them.[44]

### *Society*

Tool use among wild chimpanzees is an ephemeral individual activity. The human use of tools always has wider temporal and social reference. Tools are used by people who, if not actually working together, are doing what they do in reply to or expectation of the actions of others.[45] Each action complements many others, linking agents, acts, and artifacts scattered over space and time. The first stone tools were not nonce improvisations used and discarded by isolated individuals with isolated purposes. They were integral to a group strategy for scavenging or small-scale hunting. The evidence shows careful selection of material for tools that were reused many times and carried for miles. I'll come back to that. I'm suggesting that even at this primitive stage the use of tools indicates a high level of social complementarity, meaning an economy of purposes that react to the purposes of others, presupposing (chapter 1) the social intentionality that distinguishes *sapiens* cognition among living primates.

Chimpanzees don't learn their tools by imitating others. It is uncertain that they *can* learn by imitation at all. After more than a century of scientific primatology, "monkey see, monkey do" remains an unconfirmed apothegm. Social learning of some form is common in many species, apes included, but not all or even most of this is imitation. For instance, by simply doing what they've learned to do, adults increase the chance that youngsters will visit a site or do something else and learn a behavior (in learning theory this is called local enhancement). Stimuli can be made enticing and foster learning merely by association with conspecifics, as when smelling a new food on nest-mate's fur enhances the likelihood of sampling the new source.[46]

Chimpanzees are good at learning about the latent dynamical affordances of things (what they can be made to do) by watching others manipulate them (specialists call this emulation learning). They are much less good at learning a new

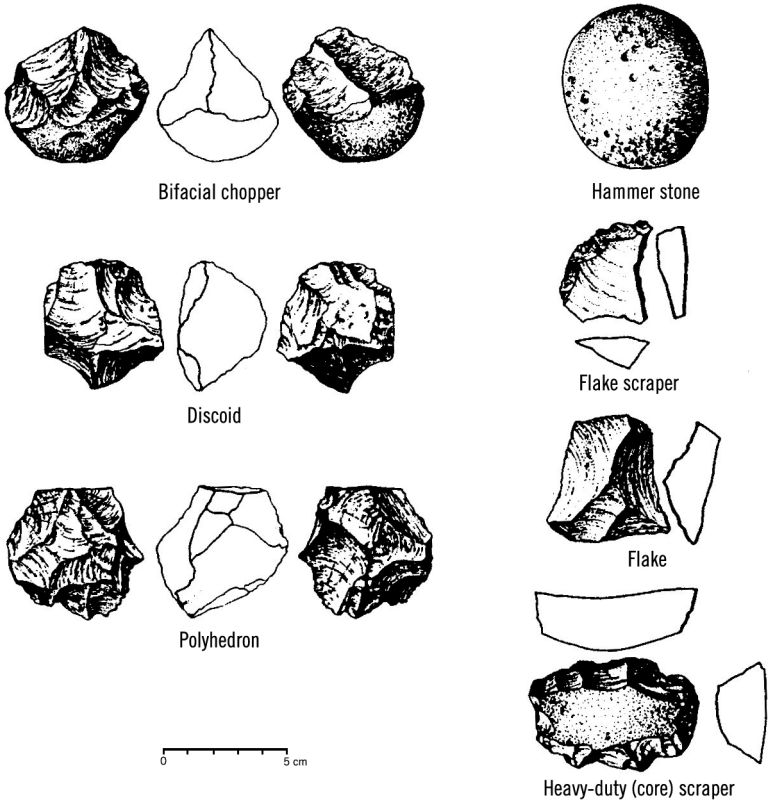


**Figure 2.2** Oldowan Stone Tools, more than 2 million years old. Reprinted from Nicholas Toth, "The Oldowan Reassessed," *Journal of Archaeological Sciences* 12 (1985): 102. Copyright © 1985, with permission from Elsevier.

behavioral strategy, a new way of doing something, from watching how others act, which is imitation in the careful sense of the word. Such imitation becomes teaching when the learner does a thing as another did *because* the other did it that way, and did it with the intention that the learner do it too, the same way, not just to the same result. Learner and teacher must appreciate each other as agents like themselves, with purposes and a point of view. What the learner watches is not just a movement with an outcome; it is intention and technique. With attention to technique (the *way* of doing) comes fidelity of transmission and the beginning of intergenerational norms.[47]

Imitation is not more rational or intelligent than other forms of learning. It is more social. As we've seen (chapter 1), learning not just about things and their po-

tentials but about others and their purposes is the most specifically human moment of our cognitive life. By the first birthday human children have learned to see intentionality, to see qualities like plan, purpose, and design, in artifacts as in those who make and use them. Only with this social-cognitive background in place can we learn how to do something by watching *the way* another does it. We see another acting, moving with purpose. We see the goal and the strategy, and can even see and imitate what another *intended* to do despite failure.

Even the most primitive blade had its economy of complementary action. I mentioned the presently oldest stone artifacts, from Gona, Ethiopia, 2.6–2.5 million years old. Authorities report evidence of their makers' mastery of conchoidal fracture mechanics, understanding the flaking qualities of materials, and selecting for better stock. They sought acute angles for striking, produced sharp edges for cutting, traveled long distances for suitable material, and habitually carried either artifacts or unmodified stone.[48] In the so-called Oldowan tools from East Africa's Rift Valley, which are presumed to be the work of the first *Homo* species, there are tools made by the use of other tools; for instance, blades shaped by hammer stones (figure 2.2). Wear analysis suggests these blades were used on wood, presumably to make other tools, as well as on hide, bone, and tissue. The tools also appear with the earliest evidence of an organized dwelling floor. From the first trace, Paleolithic encampments reveal a spatial economy that complements the economy of complementary action and tools. Dwelling areas divide into functional spaces (butchery, skinning, rock knapping), and are optimized for minimal ground occupation. By contrast, dwelling space for apes is limited to an ephemeral nightly nest.[49]

A stone tool is not just a shape or form. Its effectiveness relies on an economic coordination of the manual, social, and cognitive. Each use is a moment at which these orders intersect to a consequential effect. The difference between a rock and a stone tool is like that between a gift and a bare thing. What makes a gift is another's giving, situating the gift in an economy of exchanges. What makes a rock into a tool are the complementary social relationships of an economy (however primitive) linking the stone and its form to agents, actions, and other artifacts. As we've seen, chimpanzees lack a cognitive adaptation for socially complementary behavior. Yet it is precisely that which enables a rock to become a tool. Chimpanzees may use rocks but they never use tools because they are incapable of socially complementary action, which is the behavioral foundation of the sociotechnical economy without which tools do not exist.

### *Technical Economy*

The movements required for stone tool making are peculiar to that activity and not much like movements a pretechnical forebear might have made anyway.

Chipping a stone blade for whittling sticks entails an unlikely series of movements that would probably not be combined if it weren't for tools and technical purposes. When chimpanzees use their "tools" they use the same repertory of grips, postures, and movements typically employed in feeding. Rather than anything specialized for tools, their behavior is what you'd expect from general intelligence, conditioned learning, and primate anatomy.[50] The ease with which we link our purposes to those of socially complementary others is matched only by the ease with which this social intentionality extends to tools and other artifacts, which become nonhuman partners in an economy at once social and technical.

If, in need, you reach for an unattached environmental object, you may use something *as* a tool, using a paperclip as a needle, say, or a rock as a hammer. But it's risible to describe a carpenter engaged with hammer and nails as manipulating unattached environmental objects. Obviously there is more to tool use. I think the "more" are other tools, other users, and the socio-technical economy that links them. An economy is a network of reciprocally conditioned and conditioning units. For economic entities, to be is to circulate, to be exchanged. You cannot commence with a single word, then add two or three more, and eventually build up a language. You don't have the word until you have the language, the syntax, the economy. So too for coins, commodities, kin, tools, or indeed artifacts. These entities have no existence apart from innumerable complementary relations to other equally relational entities, economically displaced over the space and time of a culture.

A chimpanzee population in the Congo gave researchers new evidence of material selection and preliminary modification in their "tools."[51] The tools are implements for termite fishing, and include relatively stout sticks for puncturing nests, and fine probes or lures to extract the prey. Termites in this region make two kinds of nest, either subterranean or aboveground. Local chimps select different puncture sticks for different nests. Stocks of *Thomandersia hensii* are preferentially selected for penetrating subterranean nests, which apparently require a good dig. Sources of the wood may be tens of meters distant and not visible from the nest site, and these sources are revisited on later occasions. Sometimes individuals arrive at the feeding site with appropriate tools in hand, though more than two-thirds of the sticks used for puncturing were reused from other occasions when they had been left at the site. Apparently the animals are less discerning when it comes to puncturing aboveground nests, though they still seek stocks of diameter and length appropriate for use, whether it is to puncture or lure. As for their lures, a stick is first cut to size and stripped, then one end fashioned into a brushy tip by raking it though partially closed molars. Once the nest is penetrated and the lure stick readied, the frayed tip is wetted with saliva and quickly pulled though the hands or mouth to straighten and compact the frayed fibers before it is inserted and swarmed by the hapless prey.

These observations confirm that chimpanzee tools are what I'm calling proto-tools. A thing is picked up, altered in some way, and made to facilitate action it would not have facilitated without manipulation. Even a stone for breaking nuts works like that. Something that does not facilitate—a rock on the forest floor—is changed, modified in position, trajectory, and kinetic energy in a way that facilitates eating a nut. Proto-tools fall short of full-blown tool use because tools are made to work together, and only *work* when other tools (and other agents) work too. Each tool is part of a technical economy of other tools, just as use is part of a social economy of complementary action. The very functionality of a tool depends on other tools (and other agents) doing their job.

The Congo observations show the principal characteristic of proto-tools—a circumstantial, environing object is manipulated from a nonfacilitating to a facilitating posture. To most researchers it's apparently obvious that that's tool use. It isn't. It's not at all the same as the human use of tools. The difference is *artifacts and their economy.* When human beings use tools, *what* they use is already an artifact, already the work of other tools on other, economically displaced occasions. Nothing in chimpanzee behavior shows this economic integration of complementary action. In selecting appropriate wood for penetrating a nest as in preparing a lure, the behavior is technically isolated, unimplicated, unarticulated, complementing nothing others do at other places and times with other tools. Protolanguage becomes language with the supplement of syntax. Proto-tools become tools by adding the complementary tools and actions of socio-technical economy.

### *Aesthetics*

As soon as we see them in the archaeological record, stone tools are already closer to a hafted spear than a chimpanzee's termite lure. From an early point they have normative shapes, ways they are supposed to look. Standard forms cannot be individually acquired by trial and error. Nothing prevents inevitable drift from the standard, yet there's robust evidence against drift; for instance, the million-year continuity of the Acheulian teardrop form at sites from India to western Europe. Tools do not exist apart from a culture capable of ensuring the reproduction of a normative form. That requires somebody to care how things are made. A tool is not just useful. It is an aesthetically coherent perceptual form—not just made but *right.* Technical culture requires the discipline of a perceptual, aesthetic norm; where such norms are not in evidence, there are no tools in the careful sense of the word.[52]

The so-called Acheulian handaxe is an example of a normative form (figure 2.1). The teardrop shape is very old, perhaps the invention of *H. erectus,* from 1.5 million years ago. It is the second oldest stone tool form, and a monument to the

first "revolution" in lithic technology, the Acheulian being the first newly conceived stone toolkit after the original Oldowan tools. The more complicated shape of the Acheulian form—symmetrical and thin relative to width—raised the demands its manufacture makes on attention, foresight, and manual skills. *Erectus* initiated the hominid migration out of Africa, and they took this form nearly everywhere, colonizing the ice-free Old World from the Middle East to Indonesia.[53]

It is conventional to refer to the Acheulian form as a *handaxe,* as if we knew how it were used. We don't, nor should we trust what may seem an obvious functionalism. For one thing, sometimes the part supposedly held in the palm is itself a blade, which makes it a handaxe in more than one way! There are sites where these artifacts occur in caches by the hundreds with no sign of wear. Many are large and unwieldy and can't have been made for use. An exquisitely executed Acheulian form from Furze Platt, England is nearly a foot long and must weigh several kilograms. It can't have been made for slicing. It is more likely that it *worked* merely by looking as it does, by a compulsive, highly memorable visibility, a monument to its visual regime.[54]

Earlier I mentioned an archaeologist's observation that Acheulian forms from South Africa, Kenya, Madras, and England are indistinguishably well executed, despite material as different as flint, sandstone, quartz, and lava. The congruence is no casual matter, as these stones respond very differently to percussion. I see the congruence, and the impulse to it, the preference and emergence of a shape despite unwonted material resistance, as evidence of a normative form, a learned imperative of visual rightness addressed to the hands, a rightness that is perceptual, aesthetic, and probably owes little to the use of language. An aesthetic standard is not a mental template, and despite my descriptive language of "normative form," these exemplary artifacts remain a long way from Plato's Forms.[55] They are not the unmade originals of which everyday tools are copies. I doubt that learners or especially masters "looked to" these forms for instruction on what they were to make. Meticulously shaped and deliberately unworkable, these oversized artifacts are monuments to their own concinnity. Their manufacture was no doubt part of the culture or cultivation of the norm, but they lack the unidirectional, teleological causality Plato expected from a Form (*eidos*).

It is not the ideal presence of a mental template but the opposite, something not seen, not present, or incomplete that is the mise-en-scène of artifice. A template, remember, is a jig, that is, a device to reduce risk. Yet so far from reducing risk, aesthetic standards create and amplify it. They establish targets for skill, for which there is usually a lot of individual variation. A statistical norm can't do that, since you can't fail it; all you can do is deviate, which is just another statistical phenomenon. Skill requires effectiveness, especially in risky circumstances. Where there is no risk there is no skill, only a jig, a template, a determined system.

Chimpanzees seek appropriate material for insect lures and care enough about their shape to strip them of protuberating stems and sometimes fashion a frayed tip. Some authorities believe that this preliminary pruning elevates termite fishing from mere tool use to tool *making,* strengthening the human analogy. I'm less impressed by this detail. You cannot manipulate anything without changing it in some way. That chimpanzees can manipulate a stick into a facilitating posture at all implies an appreciation of how changes to the stick relate to an expected outcome. An animal clever enough to make a lure would have to be clever enough to manipulate away counterfacilitating protuberances. The chimpanzee's seeming attention to form is therefore not the same as that concern for aesthetic, perceptual rightness characteristic of technical action.

Technical rightness is, in part, aesthetic rightness, relying on a combination of evolved aesthetic responsiveness and pedagogical practice. Instrumental rationality cannot explain how individuals possessing adequate cognitive means might converge on the form without teaching. There is a normative perceptual regime only where there is an economy of real examples, aesthetic standards, teachers, and learners. Needless to say, that's well beyond other contemporary primates. It is *social* cognition that holds chimpanzees back from tools. They have no tools because they cannot act economically, complementarily, on well-founded assumptions about what others desire, believe, or intend to do.

The experts say chimpanzee tools are only an analogy, though supposedly a valuable one. It is time to count the countervailing disanalogies. There is no curatorship, no normative form, no instruction or practice. There is no socially complementary action, no technical economy, no mediation of tools by other tools. There is limited ecological dependence, and no evolved specialization for tools. These qualities of social and technical reciprocity, curatorship, pedagogy, and evolutionary specialization are not tertiary complications of a basic tool use paradigm. They are the circumstances of tool use in what should be the careful, scientific sense of the words. They have been those circumstances ever since *Homo,* since the first stone tools. And their stark absence in chimpanzees reveals the supposed analogy with human tools as thin and simplistic.

## Tools and Proto-Tools

Something may facilitate an animal's behavior just by being in the right place at the right time. An adjacent branch facilitates a squirrel's getting a nut. Pebbles incidentally pecked with feed facilitate a chicken's digestion. Fortunately, no one wants to call this tool use. There is something external and facilitating, but it's more like a catalyst than a tool. The branch and the pebbles facilitate just by being

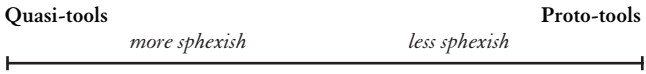


**Figure 2.3** Continuum of Manipulated Facilitation

as they are, without undergoing change. There is no manipulation, nothing taken up and modified to do the job. So let's add that. Suppose an animal picks up something that is not facilitating, and by changing it in some way makes it facilitate an outcome. A twig on a tree does not facilitate a chimpanzee's eating ants. It has to be broken off, stripped of protuberances, perhaps even frayed and moistened. Ordinarily, a stone in the ground does not facilitate cracking a nut. By selection, liberation from the ground, and imparted momentum it is made to do so.

Let's not rashly call this tool use. A more neutral description is manipulated facilitation, *making* something facilitate by appropriate manipulation.[56] Manipulation need not serve facilitation or be a prelude to use. It may be for perception, as when we pick something up and turn it in our hands with no purpose but to examine it. The manipulation that concerns me, however, is instrumental manipulation, where an agent takes up something not facilitating and changes it in a way that makes it facilitate an outcome. Facilitation alone (e.g., swallowed pebbles) is no use because nothing is manipulated, and nothing is manipulated because nothing is appropriately changed from a nonfacilitating to a facilitating disposition. The reason for this terminology, which I hope doesn't seem fussy, is to pose a question that can't be raised without it, and is usually not raised at all. Is there basically no more to the use of tools than manipulated facilitation? Are the tools that humans use just found material manipulated into a facilitating form?

The category of manipulated facilitation takes in a spectrum of animal behavior between the two poles I call *quasi-tools* and *proto-tools* (figure 2.3). Quasi-tools include a wasp's use of a pebble to seal its burrow, a finch's use of a cactus spine to dig for bugs, and an otter's use of a rock to break shells. Indeed, most of what the scientific authorities call "tool use" is quasi-tool use. What makes these behaviors "quasi" is their thin and unilluminating analogy to human tools. The behaviors lack individual variation, improvisation, or intelligent accommodation to circumstance. Quasi-tool behavior is typically a species-specific adaptation for feeding—an instinct with limited flexibility, rather than an outcome of learning, intelligence, and dexterity.[57]

Quasi-tool use may be unintelligent to the point of *sphexishness*. *Sphexish* is a clever term for behavior like that of the wasp *Sphex ichneumoneus*.[58] The female

digs a burrow, hunts a cricket, paralyzes it with a sting, and takes it to the nest. She sets it outside the burrow, enters to check, then drags the cricket inside, lays her eggs, seals the burrow with a pebble, and leaves forever. The appearance of intelligence and purpose is illusory. Every step is controlled by inflexible responses to specific stimuli. For instance, move the cricket just a bit after the wasp enters the burrow. When she returns, she'll replace it where it should be, and go back inside to check. In experiments wasps checked their burrows as many as forty times, never taking the cricket straight back in.

*Ichneumoneus*'s use of a pebble to seal its burrow is at the sphexish end of a continuum of manipulated facilitation. These are the quasi-tool behaviors. There is facilitating manipulation, though the behavior lacks intelligence, individuality, ingenuity, cleverness, improvisation, and intentionality or purpose. Moving from wasps and birds to mammals, these qualities begin to creep in. Manipulated facilitation becomes more intelligent and individual, approaching its summit in the proto-tools of chimpanzees.

The transition from quasi-tools to proto-tools comes with learned, individual, relatively unsphexish use of a peripheral effector. With that we can finally ask: How contextual is it? How intelligent is it? What of it is improvised or learned? The next step, from proto-tools to unqualified, *human* tools comes when the peripheral effectors are themselves artifacts, complementary effects of antecedent artifice, tools made by tools, artificial facilitation. To use a tool is not to *make* something facilitate (as chimpanzees do); it is to take up a facilitating artifact that has already been made and made available in an economy of socially complementary action and technically complementary tools.

The use of a tool may, of course, require manipulation. My point is that *what* is manipulated is an economic artifact that has already passed through other hands using other tools, and was purpose-made to amplify and extend the hand's functionless functionality. A proto-tool is not grasped as an instrumental potential, good for different things. Unlike a tool, which has a range of functionality rather than a function, a chimpanzee insect lure is that and nothing else. Neither does proto-tool use pass though the intersubjective dimension of complementary action and technical economy. Its use is typically the solitary manipulation of an unsocialized environment, unmediated by complementary action or an economy of artifacts.

The use of practically any tool, however primitive, requires finer motor control than the proto-tool use of chimpanzees. This control has at least as much to do with the artifact—its design—as with hands and brains. We don't require a "motor-program" to use a hammer. The program is, as it were, written into the hammer itself. Shape, heft, and balance are designed to take into account our grip, vision, and the shape and movement of our body. To use it we need only pick it

up and do what, in our hands, it feels natural to do. Allow for adjustment to proprioceptive feedback (that's when you hit your thumb), and anybody can do it. You don't need a program, you need a body like ours. Psychologist of vision Rudolf Arnheim observes, "All implements tend to include in their appearance the invisible presence of what is needed to fulfill their function. A bridge is perceived as something to be walked over, a hammer as something to be gripped and swung. This extension is so much more tangible than would be a mere association between an object and its use, or the mere understanding of what the object can serve to do. It is the direct perceptual completion of an object that looks incomplete as long as it is unemployed."[59] There is an epigrammatic definition of a tool, highlighting its functionless functionality—*an object that looks incomplete as long as it is unemployed.*

I'll say more in a moment about "functionless functionality." I mentioned that scholars favor a distinction between making tools and using them, as if it were plausible that lots of animals *use* tools but uncertain or controversial whether we alone *make* them. What would an unmade tool be? Even a quasi-tool has been made to facilitate, hence changed in appropriate ways. However, unlike wasps, otters, finches, or even chimpanzees, when *we* pick up a tool *it is always already an artifact.* The thing about human beings is not that we alone *make* tools but that only our tools are artifactual facilitations, economically displaced black boxes made by other hands with other tools on other occasions. *H. habilis* could pick up a stone and manufacture an Oldowan tool only if it already had a tool (hammerstone) in hand, a tool of favored heft (as shown by repeated use, more on that later), and preferred material gathered from revisited sites; conditions which, as I suggested earlier, seem consistent with socially complementary behavior and technical economy, however primitive.

Use of the tool's prototypical simulacra may be solitary, as it typically is with chimpanzees, but the use of tools, like the use of language, is never "private." Tool use begins in social practice, something we learn from others, for others, with others, at the behest of others. Obviously tool use can be solitary (sweeping the floor in an empty house, changing a tire on a solo road trip), yet these actions are never entirely without reference to others, including those who made our tools, sold them, taught their use, or rely on what we do with them. We see again the chief distinction between tools and proto-tools—a difference in how the implement becomes facilitating. Is it unworked material manipulated into a facilitating form? That's a proto-tool. Is it purposely made to facilitate, charged with potent functionality, by the economically displaced artifice of others? That's a tool.

These two qualities of artifactuality and functionless functionality are as near to an "essence" as tools get. Artifactual facilitation extends to nonhumans intentional qualities first discovered in other people. Like people, tools have designs

and motives. They can be figured out and used. They cooperate or throw up obstacles. It's not that we think of tools as if they were people. Rather, understanding others requires that we grasp the intentions with which they enroll artifacts in action, and consequently the "function" of that artifact in somebody's design, plan, or machine. We endow the artifact with their intentionality. It becomes a collaborator, there's something it's for, it's got a purpose, a function. In this way, facilitating artifacts powerfully extend socially complementary action, projecting complementarity much wider and deeper over space and time than would be possible without the instrumentalization of artifacts.

### *Functionless Functionality*

There is nothing a given tool is for, no tool functions. A hammer, a knife, even a bridge has no function. Is that a paradox? There is simply *nothing* wrong, no norm violated, no purpose crossed, no functional shift, in any imaginable use of any tool. If most acts involving a screwdriver really use it to turn screws (I wonder if that's true), it's a statistic, useless for proving the normativity of "function," what a thing *is supposed to* do, what it is *for*. No possible use of any tool is more central, basic, primary, designed for, or rational than any other. What it is designed for is the reliable generation of particular effects, not the "function" such effects may have for given users.

Of course, the *parts* of tools have functions. A handle is for grasping, a spout for pouring, and so on. Yet spouts and handles are not tools, and their function in a tool is not a function for a tool. The knife has a handle, it is for holding, that's its function in the system. But the knife has no function or, rather, it has any function anyone gives it by enrolling it as a mediator in action. What the knife brings to the collaboration is a definite functionality—the certainty of a range of mechanical effects. The "function" of those effects is a matter of application, emerging from concurrence with people and their purposes, rather than built into the tool and rationalizing its form.

It's no different with a bridge, which is a kind of second-order machine (chapter 4) and a kind of tool. The effect it must reliably generate is accessible stability, holding itself up and being accessible to traffic. It is the certainty of that effect for which the bridge is designed. But stability is not the "function" of the bridge or of its design. The "function" of the bridge is the function of its accessible stability in an economy of transportation. Very little information about that would come from the archive of the engineering firm that designed and built it, or be of value in understanding (structurally) and appreciating (aesthetically) its design.

We can see functions. A handle looks like what it's for. But when we see a tool precisely that evident function is lacking and up to us to supply. As Arnheim said,

a tool looks incomplete until we imagine a use. *Then* it has a "function." *Then* its shape or form is "rational" and "efficient" (or not). When we see a tool, we are usually looking for one, and what we see is a potential effect instrumental to a purpose we have. I need to open a plastic seal, and look for a knife, understanding from experience that such artifacts reliably produce an effect I can use. I enroll the knife in my action; it becomes a kind of partner. In my hand, in that context, the knife's function is to pierce plastic. But in itself, in its design, in its existence as a tool, there is no function, and no function rationalizes the form or shape of the tool as the "one best way" to realize its essential purpose.

Daniel Dennett's idea of the design stance takes the perspective of someone trying to understand a thing on the assumption that it is designed for some function.[60] If such interpreters encounter a tool, wouldn't they infer that it was designed, therefore made for something, that it has a function? Not if they're careful. It is fine to think about the function of parts in a known system, like the parts of a machine, but the function of the tool is not something a design-stance deduction about form can establish. Knowledge of function goes beyond knowledge of form to knowledge of users and knowledge of history, because a function never belongs to a tool by itself. There is no function for a tool until it is enrolled in someone's subroutine.

### *Into the Black Box*

Technology isn't just tools. Even tools aren't just tools. They are also materials, implements for other tools, and the effects of complementary tools and action. But technology begins with tools, both historically and technically. The functionless functionality of a facilitating artifact comes from how it's put together, which is from other artifacts. Tools are artifacts composed of artifacts, a construction of taken-for-granted work with earlier tools by other agents. That makes any tool (even the most primitive) a *black box*.

The image of the black box originated in automated systems theory, where it is convenient to specify modules in terms of input and output, without concern for the mechanism that turns one into the other. More recently, in science studies à la Bruno Latour, black boxes take on a life of their own. They are real things, the substance of science and engineering.[61] In this sense, a black box is a point of intersection and exchange between two networks—an economy of complementary action among makers and users, and an economy of complementary artifacts whose enrolment becomes inescapable (needles must have thread, which takes fiber, which must be gathered, processed, distributed, and so on).[62] To call them "black boxes" means two things: a reliable input-output profile; and the synthesis or synergy of subsystems, whose smooth interaction allows the system to dis-

appear into a black box for users. You don't need to understand how they work to be able to work with them.

These boxes can, of course, be opened and their mechanism analyzed if need be. Technical opacity is also relative to personal knowledge as well as imposed by task. An engineer who selects a material based on published specifications is using a black box he or she chooses not to open. However, for most people who use them, airplanes and computers are black boxes they have no idea how to open. When we do open them we find only more of the same. Step into socio-technical economy and it's black boxes all the way down. That may sound like ontological bravado. You may think that artifacts have to be made of something, so there has to be an ultimately unmade stuff. But a tool is more than a material thing. It is also a relational entity, not unlike a gift, word, or banknote. There is no first, original artifact (made by an untutored hand from nonartifactual material) for the same reason there is no first commodity, gift, or word. A tool's relations—to other people, other actions, other tools—are equally fundamental with its material form, which would not be effective without them. Take away the economy and the form loses use value, is no longer made, and does not exist.

I've mentioned Africa's Oldowan stone tool industry, which produced what for many years were the oldest known artifacts. Are even these simplest stone tools "black boxes"? Let me fill in some archaeological context. Olduvai Gorge Bed I, in East Africa's Rift Valley, revealed the first fossils of the genus *Homo,* from 1.8–2 million years ago. Stone tools, the earliest then known, were found on the same ancient living floor. Olduvai gave its name to these Oldowan tool forms (figure 2.2). The fossil hominid associated with them was originally and popularly named *H. habilis,* the handy man, although this classification is now rejected. A scientifically sounder if less dramatically styled candidate for the Olduvai hominid is *H. ergaster* (perhaps *H. rudolfensis*), attested in the region from 2.4 million years ago. The Olduvai tools were eventually eclipsed as the oldest artifacts by finds in the Lower Omo, Ethiopia, where stone tools are 2.3–2.4 million years old, and from Gona, basically Oldowan in type, 2.5–2.6 million years old.[63]

Oldowan-type tools are primitive by definition, yet it would be imperceptive to dismiss them as crude, and hasty to assimilate them to the proto-tools of chimpanzees. The capacity to shape even the simplest of these forms requires manual (or visumanual) abilities unseen in contemporary nonhuman primates. Mere trial-and-error knapping will not produce these forms. Even at this primitive stage, tool manufacture requires the right striking force directed at the right angle, as well as a discriminating choice of material for blanks and hammerstones. Experimental replication reveals that the makers of these tools were preferentially right-handed, which implies brain lateralization, the specialization of hemispheres, in contrast to other primates, which are apparently not handed and show little cerebral lateralization.

The Oldowan evidence implies capacities for concentration, attention, visumotor coordination, sequential action, and temporal planning, all exceeding modern apes and, it seems likely, australopithecines, with whom early *Homo* shared an East African habitat. Stylistically, the Oldowan (and Oldowan-looking Ethiopian) assemblages are of a piece, and the pieces couldn't be simpler. Since the new *Homo* had twice the cranial capacity of an australopithecine, it seems more likely that the first stone tools were manufactured by this species than that australopithecines started doing the same thing the same way. Archaeological evidence shows preferred sources for stone, with choice material transported for miles. There is also evidence (from microscopic wear-patterns) that Oldowan tools were used to make other tools, for instance, a stone flake used to sharpen a stick, a procedure that involves attending to differences in materials and understanding how one can modify the other, grasping the structure Raymond Tallis calls the *interlith,* the tools and materials that shape, connect, or implement other tools and materials.[64]

The explanation of the mysterious "bola stones" tells us something more about these first stone tool makers. Oldowan assemblages often contain some very well-formed spheroid stones (figure 2.2, top right). They are evidently artifacts, but what for? One theory said they were stone weights for a bola cord, thrown to entangle the legs of prey. The present state of the evidence makes the idea impossible to take seriously. The artifacts in question are some 2 million years old. To imagine hominids that ancient weaving rope, hafting stones, and designing the bola would imply technical accomplishments otherwise unattested for more than a million years. The solution was discovered by a paleoanthropologist who became adept at knapping stone. He discovered that if the same hammerstone is repeatedly used to make Oldowan forms, the spheroid results within a few hours.[65] What the spheroids show is not the precocious invention of the bola but more plausibly that these early *Homo* were either carrying hammerstones with them or returning to the same place to use the same ones over and over again. That seems to imply an understanding of their functionality, and the imposition of a technical detour, including mobilizing other tools, to enroll them as collaborators in action. Technically, that makes them black boxes.

From their first appearance, stone tools are units in an admittedly primitive technical economy that includes hammerstones, blades, scrapers, and choppers, as well as unknown contributions from unfossilizing materials. To take up a well-used hammerstone and strike a sharp edge on attentively selected and purposely transported material is to use a black box to make what will be a black box in future action. These black boxes are not so primitive that they can't be opened, and that may have happened, for instance when inappropriate stone was inadvertently (or experimentally) selected, or hammer blows experimentally or serendipitously

varied. Already we can infer the synthesis of artifice and social action, which distinguishes these first stone tools from the proto-tools of chimpanzees.[66]

Tools are like children adopted into the family Heidegger called *Mit-sein,* being-with-others. Or perhaps like slaves, which wouldn't be the only dark side of a black box. Practically everything that distinguishes human violence from the violence of other primates comes not from intelligence or language but from tools. I say *human* violence though of course I mean *male* violence. Every measure of participation in physical aggression favors men at every age in every culture, and more than 122 have been studied. Why are men prone to violence? The theory is that the behavior is an evolutionary holdover from competition for mates.[67] Yet men are not *especially* violent compared to males of other primate species. We're about as bad as baboons and chimpanzees. The difference is what's in our hand—tools, weapons. It's not easy for one primate to kill another of its species. They are too closely matched. It would be different if there were more inequality in the means of violence. The behavior of apes and monkeys suggests they would use lethal instruments if they had them. Those instruments are tools. Without tools there is no war. Violence, yes. War, never.

### *Intangible Tools*

Using a hammer amplifies the native power of the arm, as a telescope does the power of the eyes. Other tools correct for body dysfunction, like eyeglasses, or augment cognitive or communication powers, like an Internet connection or a mobile telephone. Some tools work to structure circumstances to a preferred sort of cognition, like a list. Tools can even be immaterial forms. The obvious tools are not the only ones in a blacksmith shop. So is their *position in space.* The layout, the spatial order of the shop, is itself a facilitating artifact, designed to enhance efficiency and control in the work. A spatial arrangement is not a material entity, you can't pick it up like a hammer, yet it remains bound to the tangible artifacts it organizes, apart from which its geometry has no value. Tools, therefore, do not have to be material entities, though intangible, immaterial tools owe their existence to the tangible facilitation they contribute.

Russian psychologist Lev Vygotski spoke of "psychological tools," among which he counted languages, numerals, memory techniques, writing, diagrams, and maps. Like a shopping list, these artifacts structure problems to cognition we're good at. Ivan Illich describes what he calls *convivial* tools—tools people can live with, low in counterproductivity, that can be widely shared, and enhance lives in a non-zero-sum way (your gain isn't my loss). His examples include alphabets, printing, libraries, telephones, and legal procedure.[68] These are hybrid artifacts, partly tangible, partly not, combining signs and rituals with steel and

electricity. To learn more about intangible tools let me somewhat arbitrarily dwell on alphabets.

An alphabet is not just any kind of writing, and writing (from circa 3200 B.C.E.) is older than the alphabet (circa 1400 B.C.E.). Alphabetic writing may have begun among the Canaanites, for instance the people of Ugarit (western Syria), where some of the oldest alphabetic artifacts were found (there may be yet older precursors). These people were in contact with the Phoenicians, the leading maritime trading people of the eastern Mediterranean, who modified this alphabet for their language and communicated it to the Greeks, whose alphabet eventually became the Roman script we still use.[69] Technically, an alphabet is part of a manual technique for recording the *sound* (not the meaning) of spoken language. Older, nonalphabetic scripts can do this, but none as efficiently as an alphabet, which does nothing else. Switching from the semantic to the phonemic also reduced the number of characters by orders of magnitude. Writing became a highly portable technical system that worked regardless of the language people spoke, and did not require the long apprenticeship that restricted literacy to a scribal class.

An alphabet is as intangible as the geometry of a blacksmith's shop. What exactly is the artifact? What is "an alphabet"? Not, I think, an abstract "type," a form common to all the "tokens" or inscriptions. What alphabet technology presupposes is not a Platonic archetype but a practice, above all a pedagogy (without which even archetypes would be useless). That's what is artifactual about an alphabet—an aesthetic, perceptual, graphic discipline in the artifacts of a certain practice. An alphabet is not an immaterial form (a type). It is, if anything, a habit, and the artifact of a technique, an art, a practice, more like banknotes than formal types.[70]

As an artifactual facilitation, a made means, any tool has the character of a black box. What about intangible tools? What about an alphabet? I don't think it's a stretch. An alphabet has parts, indeed, a relative complexity of parts facing specific design constraints. The letters must not be confusingly similar or overcomplicated, and their use presupposes a phonemic analysis of whatever language is being written. This black box can be opened and redesigned, and it was, several times, as the art of the alphabet wended from Canaan and Byblos to Athens and Rome.

Mathematical constants like *c* or *pi* are also intangible black boxes. To open them requires serious questions about the assumptions of their calculation. However unlikely doubt may be about such well-established constants, what stands behind them, backing them up, is not the Truth of Being. Like an alphabet, the coherence of these constants is an artifact of their technique, the art and discipline that applies them and teaches their use. Lift their veil and you discover a hybrid

coalition of mathematicians, scientific papers, experiments, calculations, precision instruments, and so on. It is the grave inertia of this assemblage, veiled by usage in dignified black, that endows the constants with their effective reality as indispensable collaborators that have to be taken into account.

Money, too, is an intangible artifact. Is it a tool? A black box? Not any one individual bill or coin is. They are not things we can open up to see how they work. Money doesn't work. It circulates, passes, has currency, but in whatever form—bullion, specie, banknotes, electronic credits—the units of money have no insides, no structure, no "works," or black-boxed parts. It is easier to think of an entire money system as a black box. If someone exchanges a bill for merchandise, we can open up the transaction, examine the presuppositions—how did the goods get to the shop, how were they paid for, why are such goods available, what was the currency, and so on. A piece of paper cannot be money, nor any artifact a commodity, without many silent partners. Yet money is not made of anything relevant to its currency. The material is usually irrelevant, unlike that of practically any tool you think of, and even when material is relevant, as in bullion, it is not mechanically (or structurally) related to functionality (currency), as it usually is with tools.

Money begins with coins, which developed from standard weights for metals, something that happened first in Lydia (modern Turkey), around 640 B.C.E.. The move to paper money was a long time coming—more than two thousand years—but it changed a lot. Although financial instruments and techniques like double-entry bookkeeping, insurance, and checks were in use in Florence from the fourteenth century, the first modern banknotes were issued by the Stockholm Bank in 1661. With paper, money loses its connection to precious metal and becomes a matter of confidence. Today, not one ounce of gold stands behind the U.S. dollar, which is simply fiat currency. Paper also paved the way to greater abstraction, culminating in the ultimate money, electronic money circulating among computers. It's been said that computers did for money what the Pill did for sex.[71] Today, coin and paper account for no more than eight percent of the U.S. dollars in the world. The rest are ledger entries, electronic credits.

What is tool-like (artifactually facilitating) about money is the system, not its units in isolation. Of course that's true of all tools. The difference is that using money is using the system, the conventions and agreements, not the material, which is just as useful to the next person after you pass it on. What is least tool-like about money is that it does not actually facilitate action. It facilitates facilitation. All money can *do* is circulate, and by itself that cannot facilitate anything except more exchange. But money can facilitate the facilitations a person has access to. It can modify the range of choices, the breadth of options, the scope of action, and withhold the same from those without credit.

## Skill and Technique

> Real grace is not found in nature accidentally; it must be sought intentionally. Made of appearances, it implies concern with appearances and with preoccupations that are essentially artistic.
>
> Paul Souriau, *The Aesthetics of Movement*

A technique is a style in bodily movement, deliberate, trained, and practiced to an anticipated result, though there may be no goal beyond the movements themselves, as in dance or playing a musical instrument. Technique often operates with tools, and even when it doesn't (say, in martial arts) it always requires technical attention to the body. It need not be taught, though if it is not taught, it is self-taught, not spontaneous or instinctual. It requires not only development (what doesn't?) but practice, which requires a context, and the usual one is an arts tradition. Technique isn't a gift. It comes from working over what is given or gifted, as farmers work over the soil, growing something that would not exist apart from the artifice of cultivation. In a word, technique is an artifact.

Skill and technique are different. A skill is a developmental potential variably distributed in a species. By "developmental," I mean that skills are neither learned per se nor inherited as such. They grow, develop, under the right conditions, which are genetic and cellular as well as social and ecological. Thinking in terms of development is an alternative increasingly favored in biology over thinking in dichotomous terms of nature and nurture, culture and biology, genetics and learning.[72] The development of individual organisms from embryos to adults is not driven by programs from either side of these dichotomies. Instead, development synthesizes what these dichotomies hold apart. Manual skills, for instance, are competencies that develop without a lot of attention to practice. They are comparable to gorilla skill with fingers. A gorilla's fine finger work in stripping a spiny pod is a better analogy to technique than chimpanzee proto-tool use is to tools. Chimpanzees are manually cleverest in the nimble care they lavish on grooming, another proto-technique, and not in their proto-tools.

What's missing from these primate proto-techniques, of course, is anything resembling art, practice, culture, pedagogy, aesthetic preference, technical standards, or socially complementary action. Perhaps we can see primate proto-technique as a platform, a launching pad for an innovation apparently peculiar to the *Homo* genus—the extension of proto-technique to the use of artifacts. Technique begins with and builds on skills but goes beyond them by organizing, combining, practicing, and artfully refining them, resulting in artifactual competence at a new order of effectiveness, which I call technical skill, or simply *technique*.

One cannot have technique without skill (of which it is a development), though one can be skilled without much technique, that is, little cultivated, artful, tech-

**BIRD — BEAK — MATERIAL**

(ontogenetically given) (found)

**Figure 2.4** Skill Assembly (bird)

nical style. Technique is skill plus technical attention to the body as an instrument—skill worked over, practiced, cultivated, disciplined by pedagogy, reorganized by technology. That makes technique artifactual in several senses. Techniques are typically cultivated skill in the use of artifacts like tools or instruments; technique is submitted to artifacts, cultivated by artifactual intervention; and technical skills are themselves artifacts of practice, pedagogy, technical culture. They are skills systematically modified to do something untaught skill can't do. The first words in Western languages for that "systematically modified" are *techne* and *ars*.

Anthropologist Tim Ingold compares the work of the weaver bird constructing its bower to the work of the Telefol women of New Guinea making *bilums,* ingeniously woven net bags, everyday implements of all-purpose hauling for both genders. Ingold wonders how to describe the difference, or whether there even is a difference at all. The bird requires practice to perform; nest construction isn't done right, or even nearly right the first time. An accomplished bird opportunistically appropriates novel materials, and uses its beak like a needle to make nine distinct stitches. Even Darwin found the result "tastefully ornamented."[73] But is it skill? Is it really like what the women do? "I do not pretend to know," Ingold says. "I remain perplexed by the question, and have yet to find an answer that is wholly convincing."[74]

I think the answer is in the artifact. Ingold and others have observed that you can't see skill by looking at isolated agents and how they move their bodies. To see skill you have to see *differences* of skill, and to see those you have to look at a context of real-life practice.[75] Where there's skill there's an assembly of what the skilled action disposes. That's where we have to look for the difference between the weaver bird's skill (yes, it's skill) and that of the weaver-women, which is *technical* skill, or technique. I see at least two orders of difference between the women and the birds in what must be assembled to perform their skills.

First there are differences in the *constituents* of these assemblies. The assembly required for weaver bird skill is suggested by figure 2.4. Notably lacking are tools or artifacts of any kind, or what they presuppose, including imitation and pedagogy. A human hand working a needle functions biomechanically as one system,

**WOMAN — NEEDLE — STRING**

**Figure 2.5** Skill Assembly (human)

sort of like a beak. Yet it is a poor comparison, because unlike a beak a needle has to be made, and its use is artifactual facilitation, which takes cultivation and presupposes socio-technical economy. There's nothing tool-like or even proto-tool-like about a beak. Proto-tools are found material manipulated into a facilitating form, which hardly describes a bird's beak. A beak is more like a finger, a source of manipulation rather than something manipulated, the bird's work closer to proto-technique than proto-tool use. Like the gorilla's nimble fingers, the bird relies on the instrumental effects of body control without the complication of peripheral effectors or proto-tools.

While there are no tools or black boxes in the avian assembly, what the Telefol must assemble to practice their skill is *nothing but* black boxes, as figure 2.5 schematically suggests. Each of these components is a black box of considerable technical density. Every element, the woman (her training) included, is an artifactual outcome of economically displaced, technically mediated, socially complementary action. Each operates reliably; its complicated workings usually don't need looking into. Consider the needle. It is made of bone. In practiced fingers it has the felicitous muteness of a well-made tool. It silently translates into the here-and-now the past and distant action of whoever made it, the other tools with which it was made, the preparation and exchange of its material, and the user's preparation in the art of sewing. The string is another intersection of economically displaced acts and artifacts. Apparently it is a two-ply plant fiber, manufactured by children of both genders. Before a woman has any string to make a *bilum,* suitable plant material must be gathered and prepared, the twining technique taught and supervised, the children's labor apportioned, and finished string collected and distributed. Once complete, the *bilum* is launched through gift or exchange into the colloquium of everyday implements. There are specialized bags for cradling infants or carrying awkward shapes, and distinctive weaving for widows and fully initiated adult men. And this is supposed to be primitive!

I mentioned two orders of difference in what must be assembled to practice your skill, depending on whether you are a bird or a Telefol woman. One is the difference artifacts and their economy make, a difference that shows up in the thoroughly artifactual quality of practically everything a *technically* skilled performance must assemble. The woman's skill has been cultivated by art or *techne,* reengineered for collaboration with tools. A second order of difference arises from the conditions under which these different assemblies are set in motion and made to

work. Exercise of the weaver bird's skill is conditioned by its evolution, anatomy, and development, which are, of course, equally conditions on the exercise of human skill. Beyond these, the Telefol woman's skill with needle and string is the work of many other people making many other things. She cannot exercise her skill without all of them too, all those other people, other artifacts, and other skills. Skill like hers *does not exist* except as a moment of socio-technical economy.

That's very different from the weaver bird's skill. Put this bird in its accustomed environment and everything the skill requires is available—after all, the behavior is an adaptation to that environment. A given bird's weaving a bower is independent of any complementary behavior by conspecifics. Of course, the birds would not exist or weave except for ancestors who wove and flourished, evolving the instinctive behavior of the species. But in the development of an individual, whether one bird weaves or not has practically nothing to do with what any conspecific does or does not do. By contrast, the felicity of the Telefol woman's action depends on innumerable skilled performances by others with the same or different tools. The weaver bird is not without skill but the skill is atechnical, not artificially amplified or modulated. It is skill at the zero degree of technical mediation and, I suggest, skill *such as we never see it in humans.* Human skills seem invariably embedded in artifactual, technically mediated assemblies. Our skills are usually technical skills, techniques. They may lack flair or individuality, but they are nonetheless the work of art or *techne.*

The skill that grows under training is skill with a body that has become an artifact. Consider for example dance or martial arts. Skill lies in the performance of different postures and movements, including their combination, timing, and muscle tone. Such skill is properly called technical. It arises only in an artifactual milieu (dance or martial arts studios), and the dancers or karatekas work as diligently on their bodies as a sculptor on a stone. As Rudolf Arnheim observes, "the performer's bodily sensations are detached from [the] self, which observes and controls them as a painter observes and controls the visual forces produced by shapes and colors on the canvas." That may be why people with extraordinary technical skill (ballet dancer, kung fu master) can't be distinguished from rank amateurs in tests of biomechanical component abilities.[76] And why, again, differences in technical skill can't be seen outside a theater of practiced performance.

If we look closely at such performances, we see that highly skilled people never perform their actions the same way twice. Let it be the same person, the same task, the same equipment, the same conditions, the same day—no two technically skilled movements are biomechanically identical. Such action appears to be compiled on the nonce from different components in different individuals as occasion demands. Russian experimentalist Nicolai Bernstein showed that the highly variable movements of skilled performance correlate with high *invariability* in the *mechanical*

movements of any tools or instruments. Trace the blacksmith's muscles and bones and you see the usual eccentric variability of skilled action. Attend instead to the hammer, the anvil, and the material being worked, and you see carefully regulated precision action of high mechanical effectiveness.[77]

The right conclusion seems to be that skilled movement is not generated by anything like a stored computer program and, once more, how mistaken ancient theory was to suppose that *techne* proceeds under the guidance of a form or idea. Even the most habitual action is an improvisation. As Paul Ricoeur observes, "All the monographs on the acquisition of habits point to this curious relation between the intention which launches out in a specific direction and the response arising from the body and the mind, which always has the air of an improvisation. This is familiar in the case of skaters, pianists, and even aspiring writers. Habit only grows through this type of germination and inventiveness concealed within it. To acquire a habit does not mean to repeat and consolidate but to invent, to progress."[78]

## Implements and Utilities

Human skills are practically always technical skills, meaning that they bring technique, cultivated practice, to bear on skill, amplifying and organizing what some or most people can do by uncultivated development. Human skills may not require tools, but they are always technical in the sense of being mediated by other techniques practiced with other tools by other people at other times and places. You might think the converse would hold, too—that any tool can be used more or less well, with greater or less skill or technique. Yet this seems not to be so. Many tools *cannot* be used *well* or with any style or individuality of technique. I call them *implements.* Like tools, they offer artifactual facilitation, but unlike tools they make practically no demand on technical skill and resist any effort at artfulness in their use.

A clock is an example. We use clocks to tell time, but no one can use a clock better than others. No one can use their eyeglasses better than others. Electrical utilities are another example. The electricity coursing through our circuits is entirely artificial, made by damming water, burning coal, or splitting atoms, and channeled into our chambers through a network even experts find difficult to follow in detail. Electricity (constant current) is nonexistent apart from our contrivance. It is a made stuff and infinitely useful, though no one can use it better than others. Electricity is not a tool but a fuel of tools, an indispensable artifactual moment in the implementation of a very important and bogglingly heterogeneous class of technological instruments.

Implements and utilities are intrinsically technological—technical accessories required to implement other tools. They are all about interface, which is the motive

of technology; they exist to implement other tools and materials. One usually can't even *use* implements without also using whatever tool or device they implement. One cannot use a clock except by using (or planning the use) of something else. The same goes for electricity. It is astonishingly useful but only if you have devices for it to implement. There is no way to use electricity or a clock except as implements to the use of other tools and materials. These accessories to tool use include a humble device like a paperclip, implement to the artifactual assembly of an office, or a paperweight, even if, as in my case, it's a stone taken from a stream and therefore apparently not an artifact. A paperweight does not so much *do* something as hold off certain changes, contributing to a stable theater of application for the other tools of the writing table, especially beside an open window. The paperweight can't be used (as it is) apart from using papers, tables, windows, and so on.

Some implements are complex works of many parts, like a clock. Others are less constructed than diverted. Our so-called utilities are like that, especially gas and water. The natural gas in the bowels of the earth is not constructed, but it takes a prodigious construction to divert it to the furnace in my basement. Lifting a stone from a stream makes a paperweight, not a stone. Instead of constructing the rock I divert it, removing it from a "natural" cycle of changes to give it an "artificial" place in the artifactual scaffold of my office. You could almost say I domesticate it, making it an artifact just by using it as one. Whether burning gas in a furnace or using a stone paperweight, something that is not put together out of ready-made parts is subjected, domesticated, regulated, and artificially made available for the more or less skillful implementation of other tools and materials.

It is not enough to say that human beings depend on tools. Neanderthal depended on tools and was satisfied to use the same ones for many hundreds of millennia. *Homo erectus* used the same stone tools for more than a million years, colonizing from Africa to China. I can't see modern technology as an extrapolation from these early technics. Before that technology became possible the human relationship to tools had to change. I describe the change as one from a species that "depends on tools," as Neanderthal and *erectus* did (sometimes even using the same ones), to a species that depends on *knowledge,* understood as the cultivation of superlative artifactual performance. I suggested (chapter 1) that this horizon of knowledge correlates with the art of the Upper Paleolithic. With knowledge, what had been a static technical economy of inherited habit (inheriting the developmental contexts in which habits are reacquired each generation) becomes a dynamic economy of emulation, competition, and art in artifacts. From this point of our history onward, our adaptation begins to thrive on the superlative artifact, meaning what is artful, artistic, well made, well done, well designed—a work at once of art and knowledge.

# 3. THE AESTHETIC

Terraced pavilions—mountain forests: It never
was necessary to distinguish between them!

Su Dongpo

Tools are not as simple as philosophers and behavioral scientists have supposed. Neither is aesthetic preference as subjective and undiscussable as its detractors assume. There is more to aesthetics than the private sentiments of people's emotional side, and there's little that is truly arbitrary in what people prefer or respond to. Differences are only to be expected, though they are ultimately constrained by our unshakable common evolution.

The word *aesthetic* comes from a Greek word for sensory perception. In philosophical usage, *aesthetic* signifies sensory responsiveness to things—a perceptual, felt response to what is sensibly present, especially for sight and hearing. Any perception is to some degree arousing. As Titchener said, you can't show people wallpaper and not affect circulation and breathing. Electrocortical, electrocutaneous, pupillary, and cardiovascular indices all reveal the arousing potential of color, pitch, and other perceptual qualities. Enhancing such responsiveness are perception's so-called collateral variables—novelty, surprise, complexity, uncertainty, conflict. These qualities, which depend on structural properties of the stimulus, have a disinterested, imaginary, contemplative appeal that distinguishes an aesthetic response to a beautiful landscape, face, or graphic design from the pleasures of taste or smell.[1]

By aesthetic preference I mean preferring among alternatives on look and feel. We may be selecting mates, territory to explore, the form of a stone tool, or graphic designs. You don't reason your way to an aesthetic preference as, given a technical end, you might reason to a preference for waterproof epoxy or a lithium-ion battery. Not all preference passes through deliberation or is linguistically mediated. Some comes from a felt awareness that one rather than another conspicuously artifactual assembly is more agreeable to be around, easier on the eyes, readily remembered, recognized with pleasure. It seems likely that something of this responsiveness was adaptive in human evolution. But it isn't only in Pleistocene Africa that aesthetic preference proved advantageous. Since then, technical choices have proliferated. The more technological an artifact, the more options that accumulate at every interface with other technologies, the more options, the greater the scope *and necessity* of design's aesthetic moment.

## Preferential Perception

> The decisions, choices, and preferences of individuals act at the population level as forces that shape cultural evolution, along with other processes like natural selection.
>
> Peter Richerson and Robert Boyd, *Not by Genes Alone: How Culture Transformed Human Evolution*

We should bear in mind the range of items and occasions that elicit feelings of aesthetic presence and preference:

- Landscapes
- Other animals, including their movements and acoustic behavior (birdsong)
- Daily or seasonal cues to changing environments (dawn, dusk, storm)
- Human body (naked or clothed)
- Status cues (scars, jewelry)
- Skillfulness, for example in speech, athletics, music, tools, or weapons
- Food, including cues of nutritional value (the color of ripe fruit)
- Ideas, including classifications
- Artifactual shapes and patterns, on their own or combined.

Ever since Darwin, evolutionary theory has interpreted aesthetic preference as an adaptation. But what exactly is adaptive about an aesthetic response? One not very subtle approach concentrates on preferences that contribute to the probability of mating and ignores the rest. Freud is an example: "There is no doubt that the concept of 'beautiful' has its roots in sexual excitement and that its original meaning was 'sexually stimulating.'" The love of beauty is "a perfect example of an impulse inhibited in its aim. 'Beauty' and 'attraction' [*Reiz*] are originally

attributes of the sexual object."[2] He doesn't explain how to extend the account to beautiful landscapes or beautifully made artifacts.

The evolutionary psychology of a later generation takes another tack. In these theories, a feeling for beauty is said to be an adaptive response to fitness-enhancing conditions, whether they are mates, food, landscapes, artifacts, or whatever. Aesthetic preference is described as "a judgment about the sociobiological quality of those who produce or sponsor costly signals and thus advertise for partners for sexual, political, or moral forms of cooperation." An evolutionary psychologist calls the feeling of beauty "the physiological reward for having processed ancestral cues of promised evolutionary function." The feeling "promotes further acquisition of information about the habitat [or a] potential mate." "Beauty experiences are unconsciously realized awarenesses of high fitness in human evolutionary history. Ugliness defines just the reverse . . . [B]eauty is a promise of function in the environments in which humans evolved."[3] I'm still wondering how the pleasure of lingering over a painting by Braque or music by Mozart, or rereading Shakespeare is linked to ancestral cues of biological function.

People do consistently prefer a certain kind of landscape. It has visible water, large trees, a focal point, changes in elevation, semi-open spaces, even ground cover, distant views, and moderate complexity. Such spaces are the most satisfying to look at, most appealing to enter and move through. Researchers find little variation. The preference for landscapes with water, vegetation, rock, and a balance of legibility and mystery proves notably robust.[4] The artificial landscapes of parks and gardens and imaginary scenes in painting confirm the preference for landscapes complex enough to motivate exploration yet sufficiently legible to be explored without disorientation.

Legibility is essential to wayfinding, and a landscape that throws up obstacles to the cognition we depend on to find our way is unlikely to appeal at any level. Wayfinding, meaning the ability to determine a route and retrace or reverse it, requires recalling the direction of a given place from wherever one is currently located. It's demanding cognition, which we partially offload by drawing expressive, visually compelling perceptual forms into procedures for determining where we are, where other places are, how to get to them, or how to communicate the way to others; for example, remembering to go left at the weird tree, or head toward a cliff that resembles a face.[5] The wayfinding value of such cues depends on their compulsive visibility, an untaught response to their perceptual presence.

The aesthetic response to landscape reminds us that we can't overlook nonhuman beauty or assume that it is somehow secondary or derived from a primary sexual response. And landscapes are just the beginning—there's also the work of our hands. Having made the usual assumption that aesthetic preference begins as a naturally selected perceptual bias for a good mate, an evolutionary psychologist

suggests that cues (for example, symmetrical faces) to which we respond, once established in development, generalize to things that aren't potential mates at all.[6] A preference for visually symmetrical artifacts may be an example. Body symmetry probably began to function as a visual cue for competent mates well before human beings, perhaps even before primates. The suggestion in evolutionary psychology is that it somehow generalizes or analogizes to a reaction of attention and interest to symmetry in artifacts, for instance stone tools. It is as if we look at a tool and see a mate (a cue for one), and that's why we find it beautiful.

Perhaps. It's not implausible that some aesthetic preferences, and even some of the earliest arts, may have been behavioral adaptations favored by natural selection. Sculpting the impeccable oversized Acheulian teardrop forms is probably as old as an ornamented body. The Acheulian form has been called the first artifact of aesthetic quality. Experimental research uncovered a preference among contemporary people for piercing and slicing shapes, particularly the Acheulian teardrop form, especially in a downward orientation, where it was found to have a sharp, agreeably dangerous appearance. Pointed shapes are preferred over rounded or oblong shapes, and people prefer glossy surfaces, especially connoting wetness. Fascination with the look of python scales (over plain or plaid) has been demonstrated in seven-month-old infants. Such preferences correlate with a level of physiological arousal that may enhance memory as well as engender feelings of both enticement and caution.[7]

Another evolutionary psychologist writes of the aesthetic response to artifacts: "Our aesthetic algorithms whisper to us: Whatever can be produced cheaply cannot be beautiful." He thinks that only an expensive artifact, taking into account all forms of cost, is perceived as beautiful. For instance, it is precisely in pathologically risky environments, where scarring is expensive (that is, dangerous), that these highly visible, unfakable signs of good immunity (for those who survive them) contribute to the aesthetic attraction of mates. Again the conclusion: "beauty equals difficulty and high cost. We find attractive those things that could have been produced only by people with attractive, high-fitness qualities such as health, energy, endurance, hand-eye coordination, fine motor control, intelligence, creativity, access to rare materials, the ability to learn difficult skills, and lots of free time."[8]

This account obviously doesn't apply to the beauty of a landscape, animal, flower, storm, waterfall, or child's face. Yet I am haunted by that line, *whatever can be produced cheaply cannot be beautiful.* Overlook the gratuitous reference to algorithms, or that it doesn't apply to beautiful children or landscapes. Still, with respect to anything technical, anything assembled or constructed, *is there* cheap and easy beauty? I doubt it. Think of a well-machined nut-and-bolt fastener or a mass-produced glass bottle. Either may have aesthetically agreeable qualities; for

instance, a bottle's graceful molded curves and edges; or the fluid precision of the bolt's movement over the threaded nut, the rigorous symmetry of machined edges, the gleam of clean metal. Either may be had for next to nothing, but this is not cheap and easy beauty. These artifacts are cheap only if you mistake price for cost, and easy only if you mistake availability for fabrication. There is nothing cheap and easy about the technological infrastructure that makes well-made hardware and glass cheap and easy. It would be impossible for an individual starting from scratch to make something as simple as a steel bolt or a glass bottle, and an intuition of unseen powers may be part of the fascination of such artifacts.

Any value the look of a landscape, face, or tool may have had as an adaptive cue depends on their compulsive visibility. They are not compulsively visible *because* they are adaptive cues. Their adaptive value (if they had it) presupposes a compulsive visibility that has to be explained on other grounds. Vision is a highly adaptive trait, no doubt about that. But how and why particular visual objects unsettle or fascinate us with their compelling visibility is better understood not by hypothetical scenarios of an ancestral environment, but from the action of perception itself. To prepare a way to that perspective I need a few words on the old idea of *expression*.

## Expressiveness and Presence

A lot has been written about art and expression. Many people take it for granted that the point or value of art is to express something about the artist, his or her feelings or identity. The idea of linking art and expression seems to begin with the Renaissance artist and architect Leone Battista Alberti and his book *On Painting* (1435), and in Leonardo's *Treatise on Painting* (circa 1482). Both say that a painting should affect the spectator, who should relive and thus understand what the work represents. A convincing depiction of sorrow should make us want to cry.[9] Only such images are *expressive* in the way these Renaissance artists think the best painting is.

This idea remained an appealing one down to Henri Bergson and Leo Tolstoy at the end of the nineteenth century. Despite Tolstoy's iconoclastic contempt for Renaissance art, he follows Alberti's line on expression in *What Is Art?* (1896).[10] The point of art is to communicate. We use language to communicate ideas, and we use art to communicate feelings, which is expression. Art should cause the audience to feel the very feeling the artist felt. A sincere and moving story told over a campfire is Tolstoy's model for what art should accomplish. The worse the fit between this sentimental idea and the European art of his time, the more Tolstoy denounced its treachery to art's vocation.

The difference between Tolstoy and Alberti is that Alberti's painter does not communicate his feelings; instead, he tries by artifice to make the spectator think and feel in a way appropriate to the painting's narrative. That has nothing to do with how the artist personally feels about anything. Tolstoy imposes a requirement of sincerity on artistic expression, transforming it from a fictive, imaginary, perceptual, contemplative value to a communication with a truth-value. Art, for Tolstoy, is not a private imaginary delight. It is a communication and should tell the truth, in this case, the truth about the artist's feelings. The insincerity that divides Caravaggio the thief from the blameless Virgin he depicts makes the work cunning and truthless.

Ideas about expression were revisited by historical and anthropological thinkers in the nineteenth century. They claimed to find in art the expression, not of individual feelings (those of the artist or a depicted figure), but of a *Volk* or people. A people's art is an expression of their psychic unity, their collective soul or spirit, as are their myths and language. Johann Herder was an early exponent of this theory. "The mythology of every people is an expression of their own distinctive way of viewing nature."[11] G. W. F. Hegel forcefully linked this "spiritual" expressiveness to the aesthetic ideal of beauty. The beauty of a work is the truth of the spirit it expresses. This expressive beauty is an original quality of the work, which it doesn't owe to any personal feeling of the artist. The most beautiful form a people invent reveals their place in the Spirit's progress toward absolute knowledge.

Later theories emphasize Hegel's thought that expressiveness is an original quality *of a work*. What a work expresses begins with the work, and doesn't preexist in the artist's mind. An expressive work has presence, compelling visibility (or audibility), commanding attention, motivating lingering and remembering. These were also the terms in which artists of the early twentieth century described the interest of "primitive" (mostly West African) art. Such works had been in European ethnographic collections for decades before they were discovered by artists like Pablo Picasso and Franz Marc. What impressed them was not abstract form but expressive presence, the artifacts' compelling visuality, a fascinating power to excite and disquiet anyone in range.[12]

The compulsive perceptibility of expressive art has its source in the evolutionary genealogy of the senses, especially vision. Expressiveness in art is a quality of the feeling of perception—the sensation of recognizing structural similarity (isomorphism) between the look of things in different media.[13] A graphic image (a painting) is not the re-projection of something nature projects upon the eye. An artifactual image is an equivalent, a structural analogue, in a work that is at once second-order perceptual (an analysis of visual objects), and technical, translating vision into the manual terms of an artistic medium. In

such works we see not things but perceptions of things, not lions but the look of lions. Drawings and paintings do not resemble the objects they depict; rather, it is looking at them that resembles looking at those objects. In that resemblance, that structural analogy, that perceptual equivalence, lies the origin of expressiveness, presence, compulsive visibility, and the birth of the aesthetic as a response and a target for art.

Experimental work in Gestalt psychology establishes three points that bear on my themes of perceptual expressiveness and aesthetic presence:

- The primary data of perception are overall structural features. These we see first. They are not constructed from simpler perceptual atoms. Vision is prestructured; we cannot see without seeing something. Visual form is always also visual content; we never see shape without meaning. "Shape is semantic," Rudolf Arnheim says; "merely by being seen it makes statements about kinds of subjects."[14]
- As form is always content, so it is always dynamic, interacting with other, equally energetic shapes. The shapes we see have tendency and resistance, containing or exerting forces. To describe vision like that is not a subjective rhapsody. It is some of the most robustly confirmed experimental results in all psychology. Arnheim thinks the animated, dynamic quality of perception is "as genuine a property of visual objects as size, shape, and color. The nervous system of the observer generates it at the same time that it produces the experience of size, shape, and color from the stimulus input." It is understandable why perception might work like that. "Our senses are not self-contained recording devices operating for their own sake. They have been developed by the organism as an aid in reacting to the environment, and the organism is primarily interested in the forces active around it—their place, strength, and direction."[15] So that's what we see.
- Visual perception is inherently expressive. To be present for vision is to be seen to act, to move, to resist motion. That's why anything we see is to some degree arousing. It's not just *there*—it's moving, tending, beginning to change. That is the Gestalt-psychological meaning of *expressive*. "Expressive properties are adverbial, not adjectival. They apply to the behavior of things, not to the things themselves."[16]

Gestalt theory identifies an expression inherent to visual objects. My interest is in artifacts that have been made perceptually expressive by artifice and design—not expressive perceptions but expressive works. For it is this expressive way of perception that makes visual art possible. It is possible to use shapes and colors to create visually expressive designs because we see shapes expressively, charged with tendency; because colors are no less expressive; and because we readily see structural similarity in visual objects of very different media. To discover how this works and develop techniques for mimicking environmental cues of visual perception is the beginning of the visual arts.

"All artistic discoveries," says art historian E. H. Gombrich, "are discoveries not of likenesses but of equivalences . . . and this equivalence never rests on the likeness of elements so much as on the identity of responses to certain relationships." "It is precisely because these identities do not depend on the imitation of individual features so much as on configurations of clues that they are so difficult to find by mere looking."[17] We don't recognize lions in cave paintings of lions. We transfer perceptual schema that would operate in the perception of lions to the perception of the painting. We are moved to do so by the artist's success in imitating the visual cues in a medium materially far removed from the usual source. The result does not resemble an object; looking at it resembles looking at an object. We depict not things but their look.[18]

Expression can't be limited to people's emotional states. Works may express any quality we can see, including elegance, gracefulness, immobility, intricacy, monumentality, order, regularity, security, solidarity, and strength. A column may be animated, victorious, suffering, or burdened, expressing pressure, resistance, tension, and strength. Lines are both drawn and seen dynamically, kinetically, with expressive trajectory. Aesthetician of motion Paul Souriau writes, "Graceful lines are those that have been traced with an easy, free, supple hand; although they have a goal, they must not seem too hurried to get there; their direction cannot exclude a certain variety." For Wassily Kandinsky, "there can and do exist cheerful lines, gloomy and serious lines, tragic and mischievous, stubborn lines, weak lines, forceful lines," expressive on their own, without composition in an "image." Paul Bonnard writes in his sketchbook, "Relaxed lines, sober lines, turbulent lines, oscillating lines, solid lines."[19] A historian of drawing describes a line's appealing, quasi-interlocutory presence:

> Once begun, the line becomes more than a means toward an end. Insinuating itself into the drawing process, it insists upon its own role as protagonist, on establishing its reciprocal relationship with its maker. . . . The draftsman inevitably finds his attention being commanded by his own line . . . [which] becomes an active participant in the act of drawing . . . even asserting its own creative independence. And we, as viewers, acknowledge that independence when we respond to the reality of the drawn line, to its substance, its body and personality, its idiosyncratic and vagrant qualities. In searching for descriptive language adequate to our response, we invoke a full range of kinesthetic experience. Mixing metaphoric allusion and psychological perception, tactile sensation and somatic awareness, we assign values and qualities, affect and character, to lines and works.[20]

These "expressive" descriptions are not the naive projection of subjectivity onto inanimate things. They are plausible descriptions of a consequence of perception's evolution, which made it (and us) sensitive to dynamic structural

analogies in perceptual objects. *Art* discovers these perceptual analogies—structural similarities we can see in other material because of how our brain structures vision in the first place. Building in these cues gives works expressive, aesthetic, perceptual presence. I'm not thinking of presence in the epistemologically exaggerated and biologically naive terms of René Descartes or Edmund Husserl. Critic and art historian Michael Fried explains aesthetic presence as "the special complicity that the work extorts from the beholder. Something is said to have presence when it demands that the beholder take it into account, that he take it *seriously*—and when the fulfillment of that demand consists simply in being *aware* of it."[21]

That is the perceptual expressiveness of expressive artifice. Works with this quality address us not as speakers but as perceivers, beings of highly conditioned perception, which these works anticipate and appeal to. The effect of the appeal is *like* the presence of another person. Artifacts aren't subjects and don't talk, yet they are intensely social entities, deeply implicated in social intentionality. They have designs, we read them for sense and purpose, and this appealing presence can be greatly amplified by an art or *techne* that anticipates and designs for the perceptual interface.

Expressive artifacts address us without communication. Their appeal is to perception, not speech and reply. They are highly conspicuous, having been made in anticipation of perception, with artfully constructed perceptual analogies that capture attention and motivate lingering and revisiting. They do that just by how they look, without calling up discursive, linguistically mediated reasoning about what they are or mean. The expressiveness, the aesthetic presence, is limited to the duration of perception, being the felt quality of a perceptual process, and not an idea you can take away with you. Nor does it always feel good. A visual or auditory object may be compulsively perceptible even when aversive, which is the misfortunate experience of the ugly.

## The Look of Design

> Design and color are not distinct. In the degree in which color is really painted, design exists. The more colors harmonize with one another, the more defined is design. When color is at its richest, form is most complete. The secret of design, of everything marked by pattern, is contrast and relation of tones.
>
> Paul Cézanne

I explained the need to include the unintended effects of artifice among the artifacts. The reasons are ontological and ethical. Ontologically, cars and smog are equally artifactual because they are redescriptions of one and the same concerted

action in terms of its effects. Anything is "made" insofar as it is an effect of artifice, and therefore all its effects, even counterpurposive ones, are "made," that is, artifactual. From a practical, ethical point of view, extending the denotation of "artifact" to include the effects of artifice better approximates the scope of our responsibility for the failures and limitations of art and knowledge. Having secured this enlarged concept of artifact, I showed how to salvage the commonsense idea that some artifacts (automobiles) are works of ours in a way that others (smog) are not. Works are technically coherent designs, as unanticipated by-products are not. Automobiles, for all their hidden costs, are technically coherent designs in a way that smog, which is no less artifactual, is not.

Technical coherence is why works work. Aesthetic, perceptual presence is why they affect us, appeal to us, fascinate and delight us, make us linger, remember, and revisit. A flower or animal may have aesthetic presence despite having no technical coherence whatever, for the simple reason that it is not a work but an organism and therefore without design. It is also possible for works to be technically highly coherent with no aesthetic presence at all. Think, for example, of an electrical-power grid, spread over thousands of miles; a well-designed system of drains in a refinery or hospital; or a microscopic work of nanotechnology. The system may be technically highly coherent, but there is no presence for the work, nothing over which one might linger, except perhaps diagrams, which are a different work in their own right.[22]

Even a system of drains makes some concession to look and feel for the people who operate and maintain it. Probably any work has aesthetic presence (including aversion) at some level of our interaction with it. Practically any work anticipates its perception and manipulation somewhere. We're so accustomed to the expressive appeal with which our works anticipate their perception that anything of notable aesthetic presence, even a nontechnical nonartifact like an animal's face or birdsong, may appear designed, looking (or sounding) like a technically coherent artifact. The original experience of looking designed, looking made, is the appearance, the satisfying look and feel of a well-made artifact. Natural selection acting over geological time produces a similar appearance by adapting things to the conditions of their existence. The result is not design, though it looks just like it. The most artificial thing about artifice is the finish. Nature is all process and no finality. An aesthetic response to nature naively extends complimentary finality to anything that looks well put together, even if it isn't. The design—and beauty—we see in nature is an artifact of artifice.

Michelangelo considered design (*disegno*) to be the common accomplishment of all the arts, which differ only in materials and techniques. Painting, sculpture, and architecture are arts because successful works are good designs. He says, "Design, or as it is called by another name, drawing, constitutes the fountainhead and

substance of painting and sculpture and of architecture and every other kind of [art], and is the root of all the sciences." A friend remembers him saying, "There exists among men only one art or science, that is *disegno* or *pittura,* from which all others proceed, and of which they are a part." Unlike correct proportion, which can be calculated, good design requires qualitative, aesthetic judgment. "Whence," as Vasari writes, "the great Michelangelo said that it was necessary to have the compasses in the eyes and not in the hand, that is, to have judgment." "The greatest grace and loveliness that a figure may have," says another friend, "is that it seem to move of itself; painters call this the *furia* of the figure."[23] That's aesthetic presence, perceptual expressiveness, and it's what looks and usually is designed about a work.

Two centuries later, Kant saw in design the formality, the rationality, that makes works suitable for appreciation as fine art. "In painting, in sculpture, indeed in all the visual arts, including architecture and horticulture, insofar as they are fine arts, design [*Zeichnung*] is what is essential." The sequel to this remark is important. "In design, the basis for any involvement of taste is not what gratifies us in sensation, but merely what we like because of its form."[24] For both Kant and Michelangelo, beauty is a technical quality of a construction, how it is put together, which is to say design. Yet for Kant the primary construction is imaginary, a work of transcendental subjectivity. The consciousness of beauty is a purely formal play of cognitive powers, determining no concept and disclosing no object. It is a purely subjective auto-affection—what we feel is really ourselves, our mental life, especially our cognitive powers. That's the point of Kant's notorious demand for disinterestedness in the judgment of beauty. It's not the object's objectivity, its existence or material reality, that matters to beauty. All that matters is the reflective self-feeling stimulated by its appearance. There doesn't even have to *be* an object. Beauty in a dream is still beauty.

I doubt that Michelangelo would approve of the transcendental turn. Design suffers when it strays from the work of fabrication. He kept design in the work. As I read it, *disegno* is a quality of a work, a performance, and not merely an intention, plan, image, or mental representation. Of course plans and diagrams are themselves works, but they are not yet the accomplishment that proves their value. Beauty looks constructed, and the primary construction is an actual artifact, material in the first instance. Michelangelo doesn't isolate design from artifice and even presupposes it, in contrast, for instance, to the rationalism of Le Corbusier, for whom a plan is the essential architectural accomplishment and execution a troublesome detail.[25] *Disegno* is not disengaged from fabrication. Design is a process that isn't complete until a work is finished. It has no reality apart from a work, and its achievement cannot be evaluated except in terms of a work.

## Beautiful and Ugly

> The theory of beauty can only be fertile for the thought which grasps life as a whole.
>
> Bernard Bosanquet

Aesthetic responsiveness—its consciousness and feeling tone—is not by definition pleasant, though it certainly can be. When it is we usually speak of *beauty.* When the felt nimbus of perception has the opposite character, when it is disagreeable, even painful—not for personal, discursively articulated, linguistically mediated reasons, but simply as the object of your eye—we speak of the atrocious, abject, and ugly.

From the earliest philosophical reflection on beauty it was understood that this *aesthesis,* this sensuous consciousness, is a pleasure different from the taste of honey or the smell of jasmine. The experience of beauty is not an involuntary sensation, like smelling an odor or tasting a taste. It is a process, a structured duration, not passively endured but self-involved, feeding on the complexity and coherence of the stimulus. Classical thought had a number of words for this beautiful coherence—*ratio, proportion, symmetry, harmony, perfection.* These words are interchangeable in the classical explanation of beauty and lack technical meanings they acquired in mathematics. They are ways of praising a structure so artfully organized that nothing can be changed without destroying the beautiful coherence of the whole.

"Measure and symmetry occur where there is beauty and virtue," Plato says. "What is good is beautiful, and what is beautiful cannot lack proportion." Aristotle defines beauty (*kalon*) as right magnitude and arrangement.[26] I think that's another way to say perceptual complexity through coherent technical complexity, which means *techne,* or artifice and design. That explains why nothing either very large (the universe) or small (a grain of sand) can be beautiful. We don't take in the parts and perceive their proportion. That's also why, compared with vision or sound, there's little beauty in taste or smell. Despite their sometime pungent urgency these senses are seldom synthetic, more simple than coherent, lacking relatable parts. We don't usually remember smells or tastes till they come again, and can't readily imagine them or linger over them in imagination, unlike a painting, poem, or piece of music.[27]

From the eighteenth century, the classical theory underwent friendly revision in keeping with new ideas in psychology after Locke. These theories pioneered a two-factor analysis of beauty. To be beautiful, something must be complex enough to challenge perception, but not so incoherent as to be aversive. Hence the appeal of novelty and variety artfully combined with order and economy. One factor (variety, complexity) arouses and sets perception to work; the other (order,

coherence) ensures a satisfying closure. The newest thing about these theories is their appreciation of the spectator's participation in the experience of beauty. To feel the beauty of a thing takes attention to relations among elements which, in poetry and music, are never present together and have to be held in thought. Even when elements are present together, as in painting or sculpture, they cannot be taken in and dwelt upon except by repeated scanning and reflective comparison. This process is contemplative or disinterested only in the sense that cognition is disconnected from reflex translation into action, and isn't calculating, inferring, or deciding on an efficient means to an end. We are preoccupied with our own vision. In other respects, for instance, neurologically, aesthetic contemplation is *very* active and intensely interested in its data.

I don't think you can say this way of thinking about beauty is simply right or wrong. It is right as far as it goes, but it doesn't go far. While a classical unity-amid-variety may be beautiful, it's not the timeless essence of beauty. There is no such thing. Beauty is not an essence. It is a response, an interaction, a vital exchange between perception and environment. The qualities emphasized in classical Western thought and artistic practice define only one part of what world art has discovered to be competent for beauty. Other qualities explored in other traditions are no less effective; for instance, the quality Sanskrit calls *sundara,* holiness; or Japanese *wabi sabi,* humble rustic imperfection; or Navajo *hozho,* health, harmony.[28] In any case, beautiful means more than *I like it.* It means perception liked because of how it looks (or sounds), and especially for the enjoyment it affords lingering and revisiting (Proust says that what the first time lacks is not understanding but memory). Whether we speak of beauty or sublimity, in a comedy or a tragedy, a painting or a symphony, the feeling of beauty is a pleasurable consciousness of artifactual presence in conspicuously designed, technically coherent, perceptually expressive artifacts.[29]

Beauty need not be overtly technical or involve parts in relation; for instance, the beautifully intense color of raw pigment in works by British artist Anish Kapoor. Plotinus made this point against the classical theory with the example of beaten gold.[30] The quality is simple—a gorgeously intense color—yet beautiful. Therefore beauty doesn't necessarily involve a relation of parts. And that's right. What's important to beauty is not technical complexity per se, but visible, manifest, compellingly perceptible artifactuality. Nine times in ten, such artifacts are technically complex, visibly (or audibly) put together from parts. But that is typical, not essential. Looking at the extraordinarily intense color of mounds and hunks of raw pigment in Kapoor's works, we do not see a technical composition of working parts. But I think we do have a marked feeling of artifactuality. Color that intense, that concentrated, looks artificial, looks like an artifact, which of course it is. Even when the color is not directly artifactual, as in Wolfgang Laib's

work with mounds of pollen, the sheer concentration of such a substance in such a setting (a gallery) is highly expressive of artifice and design.[31]

As beautiful means more than *I like it,* so ugly is not just personal distaste, for instance disliking the taste of pickled herring. The ugly is not liked because it positively repels liking, irreconcilably repulsing the very contemplation it conspicuously invites. Bernard Bosanquet called such works *invincibly ugly.* He discussed their theoretical possibility but didn't believe anything was really invincibly ugly.[32] Of course, beauty can be difficult, appreciation may take effort, but difficult beauty is not ugliness. Nor is there anything unusual about a work that contains ugly parts. Any painting of the Crucifixion is an example. It was Hegel who, in his epoch-making *Lectures on the Philosophy of the Fine Arts,* said, "the gruesome and unlucky, the harshness of power, the pitilessness of predominance, may be held together and endured by the imagination if they are elevated and carried by an intrinsically worthy greatness of character and aim."[33]

Hegel thought Romantic artists (especially painters) deliberately introduced ugliness for the challenge its artistic redemption presents to virtuosity. Yet it's one thing for art to acknowledge "the contingency of the external world and give unfettered play to the bold lines of the ugly." It's something else for a work of art to *be* ugly. There Hegel draws the line. "It would be a blunder to cling to the ugly when the ugly cannot be resolved." The ugly as such must "remain purely repugnant . . . inherently cold and worthless, because nothing comes of it except what is purely negative, just destruction and misfortune, whereas genuine art should give us a view of an inner harmony."[34]

If, as Hegel thinks, beauty is the Ideal of art, then of course art can't be ugly. David Pye makes the more intriguing argument that nothing whatever is *invincibly* ugly. "I do not believe that anything there is, if looked at, and looked at dispassionately, is intrinsically ugly." "It may be empty and devoid of beauty, but that is another matter. If we call a thing ugly we do so either because it is in a style against which we are prejudiced (and all of us are so prejudiced in one way or another) or because the thing has unpleasant associations." John Constable took the same view. "There is nothing ugly; I never saw an ugly thing in my life: for let the form of an object be what it may,—light, shade, and perspective will always make it beautiful."[35] What's being claimed is that there's no *aesthetic* phenomenon of ugliness. What we *call* "ugly" has nothing to do with aesthetics, with reflective perception and its feeling. It's a matter of (excusable) prejudice and subjective associations. Beyond that, there's nothing that's outright *ugly.* There's only beauty or its absence.

However, there seem to be artifacts that disappoint and even repel the perceptual attention their conspicuous artifice attracts. You don't want to dwell on them, not from prejudice or unfortunate association, but because of the aversive

incoherence of their perception, which, however, is difficult to ignore. The *squalid* can be as conspicuous as the beautiful, though no one enjoys lingering in its presence. At the same time, it's not easy to avert your gaze. If it's there at all, it's in your face. The invincibly ugly combines these qualities of compulsive perceptibility, being not inconspicuous or easily missed, and aesthetic aversion, meaning dislike of the experience, the perception, just as a perception, because of how the seeing or hearing feels.

Ugliness is a felt aversion, rooted not in subjective association or prejudice but in the human organism and its evolution. Does that mean everyone must feel the same ugliness? Of course not. Certainly there's not the subjective necessity of universal agreement Kant imposes on the judgment of beauty. In sensitivity to ugliness as in other human qualities, we should expect variation. Nevertheless, people's feeling about what's ugly is not as arbitrary as some may think. In the next chapter I'll discuss the remarkable unanimity among engineers and the public about the ugliness of some notorious bridges.

Philosophers have said little about ugliness, possibly because they are not convinced it exists. A contribution to the limited literature on this topic sketches an interesting if flawed topography of the ugly.[36] As there are many beauties, so the unappealing appeal of the ugly takes different forms, which this account discovers in the vocabulary of aversion, and reduces by analysis to ten genera of ugly:

1. The Noisome: gross, squalid, sordid, gruesome, filthy, decayed, corrupt.
2. The Abortive: deformed, defective, feeble, abject.
3. The Irrational: awkward, incongruous, confused, inapposite, bizarre, otiose.
4. The Derelict: stupor, inertia, insensibility, inanition.
5. The Maleficent: evil, brutal, cruel, harsh, malicious.
6. The Wanton: reckless, cowardly, degraded, morbid, defiled, depraved.
7. The Despicable: treacherous, perfidious, ungrateful, villainous, corrupt.
8. The Egomantic: pretentious, sycophantic, dilettantish, meretricious, counterfeit.
9. The Egopathic: censorious, contemptuous, presumptuous, tactless, unctuous.
10. The Wretched: dogmatic, illiberal, irascible, uncivil, profane.

1–3 seem right to me as moments of ugliness, as does 8. I have doubts about the rest. I wonder if they are really aesthetic responses. They seem to favor responses to the actions (or inactions) of others rather than to the perception of artifacts. Most of the adjectives used to specify 4–7 and 9–10 describe responses of moral feeling to behavior rather than an aesthetic response to perception. The distinction between a moral response and an aesthetic one has to be handled carefully. We have to be careful not to be too careful. Kant was too careful. He enforces purity, allowing no slippage between moral and aesthetic judgment. Morality is

about the moral law and nothing else. Beauty, with its sensuous, disinterested pleasure, doesn't get into it. The purification works both ways. If you approve of a work of art because it depicts virtue triumphant or immorality chastened, then you are not judging beauty, your liking is not disinterested, and your judgment philistine.

An evolutionary perspective can't abide Kant's dichotomies. Aesthetic responsiveness and moral feeling are not distinct spheres of transcendental mental reality. They are interpenetrating responses rooted in two relatively autonomous organic systems, one being perception, the other what Darwin called our social instincts, the biological foundation of morality.[37] Ugliness violates perceptual, usually visual feeling. Immorality violates social feeling. As outcomes of the same evolution, instincts of the same species, phases of the same neurology, these responses are not contained in sealed compartments. Nevertheless, other people's behavior is not the primary *releaser* of aversive aesthetic response. That releaser is an artifact, especially one with a paradoxically unappealing appeal. It is conspicuously artifactual, and we are free to respond "contemplatively," without exciting social instincts or moral feelings, as would happen in the presence of another person's action.

Aesthetic presence is the conspicuous appearance of artifactuality, and we are introduced to artifacts as collaborators, quasi-others, nonhuman but intentional. Hence their peculiar presence, with its quasi-interlocutory appeal, an invitation to read for motive, means, design, purpose, as we read other people. The feeling of ugliness arises where such attention is invited and disappointed. The usual cause is bad work, as in a crude or hasty job or a beginner's effort. Ugliness may also be the effect of pursuing cheapness, as in one sort of ugly public building. There can be inadvertently ugly arrangements of the environment, like dead birds in an oil spill. There is also an ugliness peculiar to photographs, for instance photographs of atrocity. These may be compulsively perceptible, difficult to ignore in range, luring yet repelling. The unease their perception instigates is an aesthetic response even if not a pleasure.[38]

Nature can be beautiful—can it also be ugly? Without being too particular about what "nature" means in this context, "natural" scenes of, say, predation, rotting corpses, monstrous births, and so on may evoke the compulsive-aversive presence characteristic of the ugly. If such sights are merely repulsive without (visual) fascination, they may be disgusting but not ugly. Even in these cases, what's ugly without being artifactual retains the look of botched work, of something gone wrong, a lack or loss of coherence. Only an artifact can *be* incoherent, though nature can mimic *this* quality of artifacts too, hence, theoretically, ugliness.[39]

The relationship between aesthetics and art is based in the distinction (chapter 1) between aesthetic responsiveness or *feeling* and aesthetic *artifice,* when the

design of artifacts anticipates their appeal to perception. Aesthetic responsiveness comes with our evolved capacity for preferential perception, but to actually contrive something aesthetically expressive takes art. My argument in chapter 5 is that art is not an essence or formal category, not the sort of thing that has a philosophical definition. It is a contingent history of what people everywhere have made of the capacity—a laboriously constructed product of cultural evolution—to anticipate and appeal to perception in the design of their works.

Then there is the relationship between aesthetics and technology. As I suggested in the introduction and will unfold in the next chapter, aesthetic rightness is a component of technical rightness in visual art no less than engineering. With some exceptions I'll mention, technically good engineering requires artfulness in anticipating and responding to a work's aesthetic, expressive presence.

# 4. TECHNOLOGY



I cannot imagine any condition which would cause this ship to founder. I cannot conceive of any vital disaster happening to this vessel. Modern technology has gone beyond that.

E. J. Smith, Captain, *Titanic*

Technology was sold to modern societies as a wonderful engine of progress. Allied with science it would liberate people from ignorance and debilitating labor, deepen and extend democratic participation, and make the goods of high culture (music, literature, and so on) universally available. It would do all of that not by social revolution (abolishing property or social class) but by applying the science of nature to the problems of humanity. A few prominent examples from the latter-nineteenth and twentieth centuries lent credibility to the picture, including improved public health; labor-saving devices for housework and agriculture; enhanced access to high culture through mass-press, radio, television, and recording; and celebrated inventions like electric lighting and motorized flight.[1]

After the mid-twentieth century, however, the prominent successes came to look like skewed samples from an overall pattern at odds with the promised boon. Other sides of technology, less optimistic, came into view, leading to the major modern complaints against technology:

- Unanticipated costs. Liberation in one direction brings new costs and problems elsewhere—automobiles and pollution, medicine and iatrogenic suffering, high-tech farming and desertification and rural immiseration.

- Social injustice. Technology's boon has not been even or humane. The brave new world of technology became a consumer economy of frivolous comforts and wasteful entertainments run on the back of the poor.
- Deskilling. Destroying competence, undermining the dignity of work.
- Democratic deficit. The decision in the United States to develop atomic weapons was made under the strictest possible secrecy. That was in time of war. Even in peace there are few channels for democratic participation in technological choice. Some barriers are of the mind, like an assumption that technology is a private matter, belonging to anyone clever enough to invent something and take it to the market; or that technology obeys an impartial ("purely technical") rationality not to be interfered with for political reasons. Anyway, we think, technological advance will benefit everyone in the long run.

I have little to say to these concerns directly, not because I don't share them but because they lie to one side of my argument, which takes an evolutionary-time-scale view of human existence, to grasp technology's relationship to art, artifice, and design. I begin by explaining my conception of technology as an economic, threshold phenomenon, and then discuss its relation to science and engineering. The latter part of the chapter is a study in the aesthetics of technological objects, taking bridges as an example. I discuss several and compare two in detail before summing up my argument on the relation between technology and aesthetics. My thesis is that good technical design (good engineering) is at once aesthetic and structural or mechanical, that good design cares for the perceptual, human interface as much as the mechanical interface of parts and systems.

## What Is "Technology"?

I resisted the equation of technology with mere technics or tool use. My idea is that a technical culture *becomes* technological when its economy mutates in a way I'll describe. I find this approach clarifying, as I shall try to show, though the effort to distinguish technical from technological goes against the grain of work in anthropology, archaeology, and the history and philosophy of technology, where it is more usual to identify technology with any part or form of production.

For example, technology is explained as "the human making and using of material artifacts in all forms and aspects." It is "the entire logic of artifice," the "rules about the way we create and transform things." Technology embraces all the "things and means used by societies to act upon their physical environment"; "all aspects of the process of action upon matter, whether it is scratching one's nose, planting sweet potatoes, or making jumbo jets." Related usage equates technology with a sum of technical competencies. "Technology" is a name for "the

densely interactive, endlessly reshaped mass of artifacts, techniques, designs, and organizational strategies, and the bodies of tacit as well as formal knowledge on which all these rest—in effect the technological base of the social order." According to this anthropologist, this base "has grown, irregularly but cumulatively and without significant reversal, throughout the entire human career," making technology "one of the cumulative, irreversible accomplishments of humanity."[2]

Defining technology in terms so universal (when did people not "create and transform things"?) makes it merely another name for the technical culture associated with human groups since the beginning of the species and even before that in evolution. "Technology" becomes as old as the *Homo* genus. To me, that's unhelpful usage. We cannot be wrong to think that contemporary civilization is technological in way that no other has been. How shall we describe it? What makes it different from the Stone Age? My suggestion is to see (modern, advanced, scientific) technology as an economic transformation of an older technical culture, a historical mutation appearing first in Europe and America and now effectively global. Technology is a new organization, a new economy emerging from a technical culture that had already undergone centuries of urbanism. But what exactly makes it *technological?*

It is sometimes thought that technology is about machines taking over from tools, or automation supplanting handwork.[3] On a closer look, though, these explanations are untenable. Much so-called handwork uses machines of all kinds —jigs, molds, gages, templates, even hand tools are machines. The finest "handmade" ceramics are thrown on a wheel turned by an electric motor. Hand tools are machines? Yes, though to understand why we have to step back and ask what a "machine" is. Franz Reuleaux, in his still authoritative *Kinematics of Machinery* (1876), says, "A machine is a combination of resistant bodies so arranged that by their means the mechanical forces of nature can be compelled to do work accompanied by certain determinate motions."[4] Nut-and-bolt fasteners, hinges, precision instruments, any hand tool—all are machines by that account. The definition is not perverse. Here is another, from a respected history of mechanical inventions: "The term machine might be applied to any contrivance in which forces are used, even if the forces are small and the actual appearance of the force is discontinuous and spasmodic."[5] That makes machines of a prehistoric fire drill or stone blade, a ballpoint pen or jet aircraft.

Hand tools are machines, mechanically speaking. Yet surely machines are "complex" and "automatic" in a way simple hand tools aren't! Well, some machines are, but we can do better than vague talk of simple and complex. A more workable division of the technical field is into first- and second-order machines.[6] First-order machines are devices that extend human capacities by exploiting a mechanical advantage. That includes hand tools, from a stone blade to a modern

scalpel. A second-order machine is an assembly of first-order machines, coupled to produce a multiplying effect. For instance, a modern bridge. It does not augment a native human power by exploiting a mechanical advantage. Rather, by forming structural members it generates an effect (load support) wholly out of proportion to any of the parts by themselves. Of course, a factory is another second-order machine. Individual workers on an assembly line may operate first-order machines, with their labor-power organized by management into a second-order machine.

First-order machines work by exploiting a mechanical advantage. Second-order machines work (when they do) by exploiting the economic equivalent of a mechanical advantage. In use, first-order machines are, of course, black boxes—open them and there are more black boxes inside. What is "first-order" about them is that by design they produce a mechanical advantage, an efficiency, an intrinsically functionless functionality. A second-order machine is a system (or nested systems of systems) of such machines, compounding and directing their concerted effectiveness to an economic end. Such installations long preceded modern industry. A millstone turned by water-power is a first-order machine, while the whole mill, with stores, shop, finances, living quarters, and so on, is a second-order machine whose "technology" is still Roman.

Industrialization is a threshold phenomenon, a pattern that arises once second-order machines begin to predominate in local and eventually wider economies, as in English cities like Manchester and Birmingham from the later eighteenth century. This industrialization can be seen as a reorganization of technics, creating the framework—legal, political, and economic, as much as mechanical—within which it became possible (politically, economically, legally, mechanically) to bring compound, second-order machines on line—machines whose "technology" was at first still medieval. The most significant technological innovations of the Industrial Revolution didn't involve machines but people, or rather, new ways of getting machines and people together. A proto-proletariat had to be trained to mesh with machines designed for efficiency, often at the expense of the operator's comfort or health.[7]

*Handmade* is not an ontological category, not primordial *poiesis.* It is a stylistic concept, meaning something like "made by preindustrial means." Nothing is ever literally made by hand, with unmediated skill ("hand") meeting raw material, with no intermediate artifice—no jig, gauge, template, tool, or prefabrication. To see what hands alone can make from material innocent of artifice look at the proto-tools of chimpanzees. The step into an economy of artifactual facilitation comes at the price of that innocence. Work done by hand includes power-driven machines (for instance, a potter's wheel), while a power tool may require more skill and dexterity than a hand tool (for instance, a dentist's drill compared to a

brace and bit). Highly skilled handwork is not always better than the artless work of automation. Skilled work can be needlessly expensive and produce worse results than mass production, while automated artifice does not imply poor workmanship. On the contrary, machined joints, finishes, tolerances, and so on can be very finely done.

Tools are machines and machines are tools. Both are black boxes, artifactual ensembles, technical instruments of functionless functionality. A civilization does not become technological by replacing its tools with machines. What's decisive is the displacement of unorganized, uncompounded first-order machines by increasingly complex and expensive combinations of second-order machines. Much that we see as notably "technological" in our own civilization are consequences of passing a threshold that can be described in three verbally different ways:

- As the economic predominance of second-order machines;
- As a steep rise in the scope and intensity of technical mediation, meaning machines that interface with other machines as much or more than with humans;
- As the ascendancy of certainty over risk in production.

These are verbally different descriptions of the same underlying socio-technical transformation. The reason is because when the larger part of production is performed by second-order machines, the density of artifactual mediation—artifacts depending on or working with other artifacts—dramatically rises. Second-order machines are made to work with other machines. They are built for coupling, are incomplete without mechanical links and extensions, and provide endless opportunity for the introduction of new machines. Philosophers sometimes credit scientific experimentation for Western technology's restless growth.[8] But technology has restlessness as its own economic principle. The "technological" machine is designed as much for the other machines it connects to as for the operator or user. Cross the threshold of economic predominance and the machinery of production exercises a standing incentive to bring new and different machines on line. The engineer's art comes into its own as an art of composition, combination, integration, synthesis, design. An engineer says, "Today's engineers have reached the point where they invest far more time in the problems of *combining* elements effectively than they spend inventing them in the first place."[9] It would be just as true to say that engineering invention is the orchestration of subsystems, which is the art of design.

With the predominance of second-order machines, the balance of risk and certainty in production dramatically shifts. Certainty in artifice is secured by jigs, templates, and other devices designed to isolate the outcome against differences of skill in operators. A hole drilled by brace and bit is riskier than one made with

a power drill, where speed itself is a sort of jig to keep the hole straight and cleanly cut. A second-order machine is not only compounded of first-order machines; these machines must work with certainty rather than risk. The only way first-order machines can be integrated into a second-order machine is if they can be made to work with certainty. The economic prominence of second-order machines is therefore at the same time a change from an economy dominated by skill and risk to one of mechanical certainty. Ultimately, however, risk is irreducible. Partly it migrates to the media of automation, reappearing as uncertainty in the production of templates, the design of systems, and so on. And partly risk is displaced from production at the price of a sharp rise in risk from other sources—uncertainties of finance, labor, resources, markets, and ecology.

The step across these thresholds was launched in Europe by 1100. Over the next nine hundred years, technical culture in Europe and America was first urbanized, then automated, then globalized, while forming historically unprecedented links with scientific research, government, and military. With urbanization the scope and scale of automated production rises. Cities provide sheltering new settings for automated systems, whose demand for specialized inputs is greater than in skilled artifice. Nomads engage in little artifice of certainty, which takes complicated gear you have to lug around. Farmers use more (for instance, the potter's wheel) because being settled they don't have to lug it. The city offers a new horizon for the expansion of automated production, which implies a steep rise in artifactual mediation, as more and more artifacts are designed to respond more and more intricately with other artifacts. The socio-technical economy of any system of cities therefore tends to replace risk with certainty, initiating the spiraling artifactual mediation that is symptomatic of technology, first in the cities, then across the planet.

Technology is not just tools or even machines. The kind of tool, the kind of machine, matters, as does the workmanship that operates them, and the socio-technical economy that embeds their use. Technology is a historical variation in technical culture, as a new species is an evolutionary variation on the theme of the genus. On the far side of the technological threshold lies the whole history of technical culture since Olduvai. Early civilizations like Mesopotamia, and classical civilizations like Rome, are still on the far side of technology, their production predominately the risky work of first-order machines. Crossing the technological threshold is like the conversion to agriculture or urbanism. All are matters of economic predominance, whether in how food is produced, how settlements are organized, or the kinds of machines and workmanship enrolled in production. In each case, something that began as a novel variation eventually became an irreversible condition of human existence, as agriculture, urbanism, and advanced technology are now.

## Drawn-out Design

> The line between the modern technological world and that of traditional crafts coincides with one drawn by drafters.
>
> Patrick Maynard, *Drawing Distinctions*

The use of drawing in a distinct design phase of fabrication is unusual (though not unprecedented) before modern times. On our side of the technological threshold it becomes usual, with the genealogy of practically any technological work including a design phase that involves drawing. The rise of technical drawing is understandable. As second-order machines multiply so does the demand for them. The more complex the technological systems, the more this demand requires fabrication to be mediated by a drawn-out design process. It might be possible to design something entirely in thought but that is certainly not the usual way nor could it be.[10] An economy of second-order machines causes technical alternatives to proliferate, continuously enlarging the problems of synergy and the scope of technical choice—shortly we'll see examples from the engineering of bridges. Drawing is an unmatched cognitive artifice for anticipating problems and inventing solutions in technological design.

Draftsmanship reached a very high level before T-squares and slide-rules became obsolete. Modern technical drawing begins with a number of graphic innovations from around 1500. There was technical drawing before then, but with Leonardo and then the coming of print the subject advanced rapidly. Graphic innovations of the Renaissance include linear perspective, projective geometry, and the cutaway and exploded view. These greatly enhanced the precision of information conveyed visually, permitting for the first time what a historian of drawing calls an "exactly repeatable visual statement."[11] Emphasis on *visual.* The drawings show visual information visually. They do not describe it, like a text, and they do not calculate it from assumptions, as in mathematics. They show it, through a highly evolved and very precise system of visual conventions (figure 4.1).

There are several types and levels of technical drawing.[12] A designer's drawing may be a schematic sketch highlighting difficult or novel features. Project drawings are done to scale with international graphic conventions. Production drawings show details of dimensions, joining, and so on required for manufacture. Presentation drawings are very finished, often with color. Maintenance drawings indicate important information for service and repair. Technical illustrations visually interpret the ideas of an accompanying text. An image or illustration can be as carefully designed as any tool. Its work is to facilitate understanding, and it works only if it interprets relevant features visually. Drawings function differently in the design stage and in construction. Finished plans

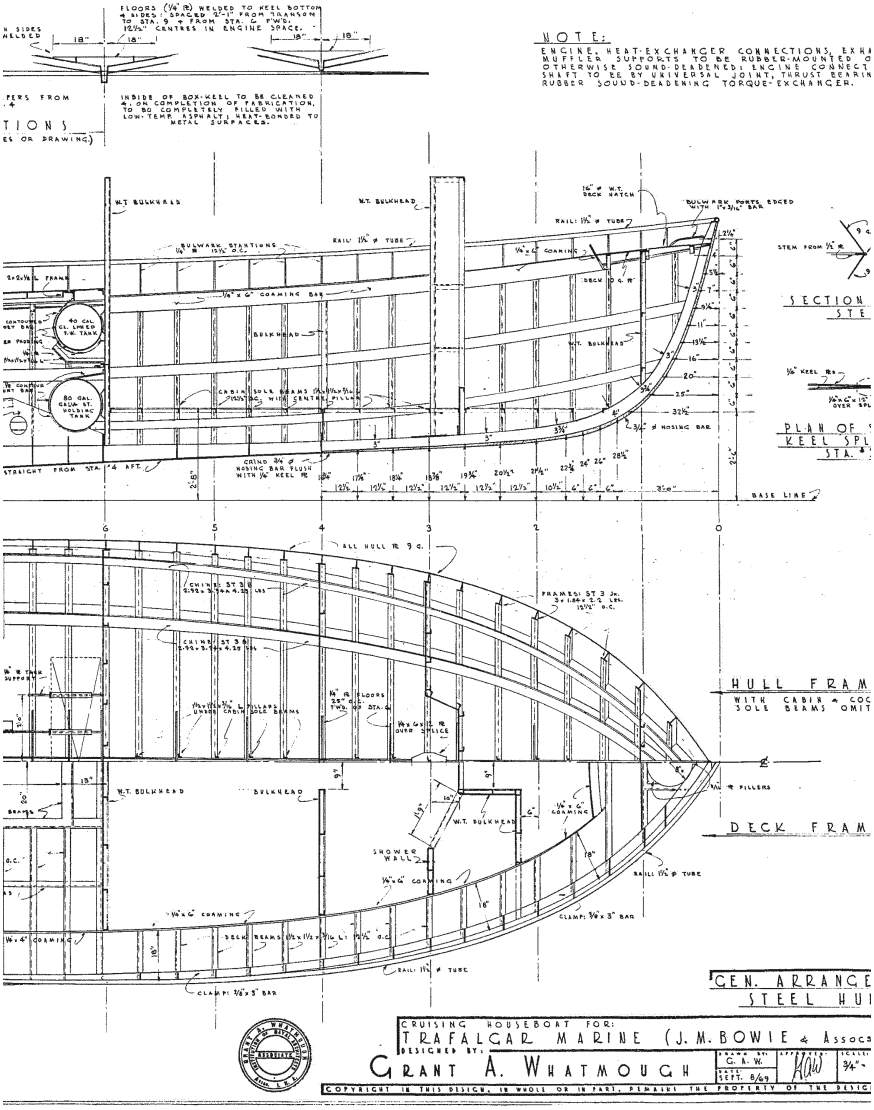


**Figure 4.1** Engineering Drawing of Cruising Houseboat. Designed by Grant A. Whatmough, INA Assoc., 1969. Author's collection.

show fabricators information required to manufacture the object. In design, the purpose of drawing is reflective, to show designers how ideas look on paper. Such drawings do not translate finished thoughts into visible form. Instead, they are cognitive techniques, artifactually facilitating skills, enrolled in the process of constructing a technically coherent design.

Perhaps it is obvious why a supple and precise visual language for describing technical objects must enhance the planning of large projects involving many workers and parts. By knowing in advance exactly what parts are required in their full dimensions, fabrication can be carried out in the most convenient order. A precise graphic vocabulary also enables designers to visualize and manipulate the project at any level of analysis, allowing even large changes at little cost. Assisted by precision technical drawing, designers can form and reform technical elements in an almost poetic way. You may recall the naval architect who said ship design "differs from the creation of poetry only in its numerate content."[13]

Thomas Newcomen apparently made no use of drawings in manufacturing the first steam engine in 1712. That's not to say he designed it in his head. Design was done on the spot, with the hands as much as the head, in the workshop and in the field. Recognizably modern engineering drawing emerges with the establishment of the Soho Manufactory in Birmingham in 1773. Soho, the first factory for the construction of steam engines, was established by Matthew Boulton in partnership with technical genius James Watt. Trained as an instrument maker, Watt followed experimental natural philosophy at Glasgow University. Drawing freely from architecture, surveying, and scientific, military, and naval draftsmanship he created the first practical means for using drawing in mechanical design, development, and production.[14]

Within a century, the drawing office was established in Britain and elsewhere as an instrument for the inception, design, control, testing, and maintenance of all kinds of production. By the twentieth century the drawing office had become highly specialized, with drafting teams for cylinders, breaks, frames, wheels, boilers, and so on.[15] Computer-assisted drawing (CAD) hasn't changed fundamentals. Whether they're produced by a person or a machine, we still require drawings to foresee the performance of things we plan to put together, to anticipate their perception and refine their visual and mechanical coherence, to control their production, and to maintain them after they're made.

Technology is a contingent history of technique, of artifactual facilitation—something that happened to human technics in a few local variations and spread. Technology is a history, which means that it is really contingent, not determined by a telos, essence, or inner rationality. It is not a name for Being. Technics, human technical culture in any form, is equally a history, though the time scale becomes evolutionary and the outcome a common human inheritance. Technics did not

have to exist—the *Homo* genus didn't have to evolve. But given the *Homo* genus and especially the *sapiens* mutation, technics fails us only at the price of extinction. Technology is the historical contingency of a global socio-technical vortex pulling everything with which machines interface over a threshold of architectonic density in technical mediation. That did not have to happen. We could still be medieval. We didn't have to cross that threshold any more than we had to cross the agricultural or urban threshold. But we did, and given that we have, it is an irreversible human condition for as long as there is a future.

## Engineering Technosciences

Technology emerges as an economy of machines that cannot work except with other machines. As this pattern sweeps through the production of a regional, national, continental, or global economy, collateral effects ensue. One is a new visibility for efficiency, which in becoming technological also becomes calculable and subject to competitive design. The shift from an economy of artifice dominated by skill and risk to one of automated certainty didn't happen blindly. It was literally engineered. The new problems of technological integration—designing devices to run devices connected to devices running other devices—advanced engineering from medieval to modern in a couple of generations. The natural sciences had practically nothing to do with this advance. The Industrial Revolution is far more an economic, political, and technological event than a scientific one. The scientists didn't prick up their ears until industrialization was so advanced as to make its methods and technical problems conspicuous.

Augustine set the tone for the medieval intellectual's view of technics. He figured that before the Fall we had no tools and no need of them. That makes their artifice sheer expediency, a rag in the storm, a hovel in the wilderness. There is no grace in technics, no transformative power, no relief from imperfection. It was knowledge that cost us Paradise, and no clever discoveries about how things work will redeem us. By 1200, however, at the height of medieval urban civilization, the contribution of technics to felicity was so conspicuous that Augustine's dismal analysis came discreetly into doubt. Some wondered whether the perfection we lost and the salvation we hope for might be attained by technical mastery and the power to command nature. Isn't God a kind of Architect? (First depicted as a craftsman in Winchester Cathedral, late twelfth century.) Isn't artifice a divine power, a saving grace? Semantic innovations parallel the new interest in technics by the elite. Novel expressions from this time include *mechanical arts, useful arts,* and eventually *technology.* The first reference to *artes mechanicae* is by John Scotus Erigena, in his ninth-century commentary on a fifth-century compendium of lib-

eral arts. Remarkable for the time, Erigena describes the mechanical arts as "man's link with the Divine, their cultivation a means to salvation." A later commentator on liberal arts, the twelfth-century Hugh of St. Victor, repeated Erigena's benediction in his influential *Didascalion:* "This, then, is what the arts are concerned with, this is what they intend, namely, to restore within us the divine image."[16]

What motivated this sea change in Western thinking? Historian of technology David Noble draws attention to a rise in millenarian enthusiasm (an urgent anticipation of the end of the world) in the twelfth and thirteenth centuries. Radical Christian thinkers reinterpreted their faith in terms of being called to a great project, the project to end all projects, Redemption by the perfection of technical mastery. Dreamers of this dream (including Joachim of Fiore and Roger Bacon) had what Nobel calls "a decidedly utilitarian thrust, emphasizing the enhancement of technological powers in agriculture, husbandry, mining, metallurgy, chemistry, mechanics, and navigation"—even encouraging "a new lordly attitude toward nature, reflecting the anticipated restoration of Edenic domination."[17]

From Galileo to Newton, the new experimental natural philosophy of the seventeenth century took a good deal more than it returned from independently advancing technics. Francis Bacon, a persuasive proponent of this philosophy, was not himself a scientist of any distinction, but as a respected European author he gave experimentation a respectable image—respectably secular, respectably useful, respectably neutral in politics and religion. Bacon refashioned the medieval millenarian theme of salvation through technology into a program for secular government. He called for disciplined experimentalists to take up problems of agriculture and industry. The appeal inspired the founders of the Royal Society of London, the world's first scientific society. The lightning rod, probably the first significant "application" of basic scientific research and an excellent demonstration of experimental utility, was invented by Benjamin Franklin, a Royal Society fellow since 1756, who refused a lucrative patent in order to make a gift to humanity of his discovery.[18]

By the end of the twentieth century the distinction between what economists call growth, what technologists call R&D, and what scientists call science was difficult to draw. There were by then more than twelve thousand large industrial research laboratories worldwide, and their work was quite as good as the best university-supported basic research, with Nobel Prizes for work at IBM and Bell Labs. Scientific instruments, material, and laboratories became industrial capital goods, and the research agenda was conditioned by the economic and geopolitical interests of the industrialized economy.

I mentioned a problem of democratic deficit. It seems unlikely that science and technology will attend to the needs of the poor with much enthusiasm, despite

their global majority. The technoscientific research and development regime has little bearing on goals that aren't backed by assets, and there's no money to be made from the poor. Instead, the demands of the wealthy are amplified, and those who already enjoy a high standard of living are preferentially served, contributing to the superfluity for which our age will be notorious, if we are not the last age already. Access to technics was not a problem of justice before we crossed the technological threshold. Everybody had about the same access to the same energy driving the same tools. Now, however, technological justice requires more than merely equal access to the products others choose to bring to market. The direction of research in science and engineering is not a "purely technical" matter rationally solved by specialist calculation. The more technoscientific mediation penetrates everyday life, the more urgent the question of justice in the technosciences.[19]

Modern industrial technoscience reverses the original economy of artifice in evolution and world history. Formerly, skilled, risky artifice predominated. Now the opposite order of mechanically certain production prevails in every "developed" economy. One consequence touched on earlier is a sharp rise in the scope and intensity of technical mediation. In a regime of second-order machines, production is arranged to generate the need for a machine at every machine. The internal, economic dynamic proliferates devices and technical dependencies among them. Under these conditions, the *linkage of machines,* the technics of systems, emerges as an object of specialized knowledge, *technological* knowledge, or what we usually call *engineering*.

Previously, the engineer (Imhotep, Daedalus, Brunelleschi) was called in only when undertaking an economically anomalous construction (like a pyramid). On our side of the technological threshold, the participation of the engineers is economically normal. A field of specialized knowledge such as engineering seems inevitable once second-order machines begin to dominate production. Engineering addresses a need that arises from technologically dense mediation, when the artful orchestration of technical systems (mechanical, electrical, structural, and so on) emerges as a problem for knowledge and an opportunity to make money. By 1850 there was a body of knowledge that had to be mastered by anyone who wanted to practice engineering.

This "technological" knowledge was historically, economically, and epistemologically distinct from the natural sciences, though it took from them what it could use and played a part in their advance through the contribution of engineering in the design and manufacture of experimental apparatus, instrumentation, and so on. Efforts to distinguish science and engineering usually focus on their different outcomes. Science discovers truths; engineering creates artifacts.

One engineer says engineering "is the making of things that did not previously exist, whereas science is the discovery of things that have long existed . . . Technology deals with the artificial, science with the natural."[20] This is not a convincing ontology. The sciences do not pursue "truth." They pursue answers to interesting problems, most arising from earlier answers to former problems. Much the same happens in engineering. A scientific advance doesn't necessarily consist in a new truth. It can be a new instrument, experiment, procedure, or material, while the engineering of objects that never existed before is part of scientific research as we know it. We should not expect from science the metaphysical truth about "things that have long existed," but the truth we *can* expect—results that hold up and provide a secure platform for new research—is a similarity, not a difference, between engineering and the sciences.

The idea that Science and Technology have to be different in some principled way seems to assume there's a logical or epistemological credential that makes all the sciences Science. How else could microbiology and astrophysics seem to belong together in a way that distinguishes them from metallurgy? No doubt there are differences in the research methods of the sciences and engineering, but I wonder whether they're greater than the differences among the sciences themselves—between, say, microbiology and astrophysics. It seems to me unlikely that there's a plausible way to characterize all the sciences all at once and distinguish them altogether from engineering or technology.

I'm not saying there is no difference between them, only that it is not a dramatic, categorical difference that sets all the sciences together on one side of an epistemological line with engineering on the other. One difference between lots of engineering research and work in almost any science is that engineers make fruitful use of experimentation without theory, a thing philosophers consider impossible in science. The experimental variation of parameters is especially important to engineering research; for instance, searching for the sweet spot in propeller pitch. That was also how Greek engineers designed their catapults and how the Wright Brothers designed their airfoil.[21] Experimental variation can provide reliable results in areas of such complexity and indeterminacy that no useful theory exists. It's a joke to say that engineering is applied science when engineers are past masters at taking knowledge where science cannot penetrate.

An example of parameter variation and its fecundity for engineering knowledge is the research conducted in the design of the Britannia Bridge (1850), crossing the Menai Straits in northern Wales (figure 4.2).[22] The designer, Robert Stephenson, was a railroad engineer (like the illustrious *père,* George Stephenson, "father of the locomotive"), and his commission was a bridge for heavy rail. The Admiralty ruled against an arch over the crossing. The inventive truss forms that flourished with railroads in Russia and North America were still in the future. A

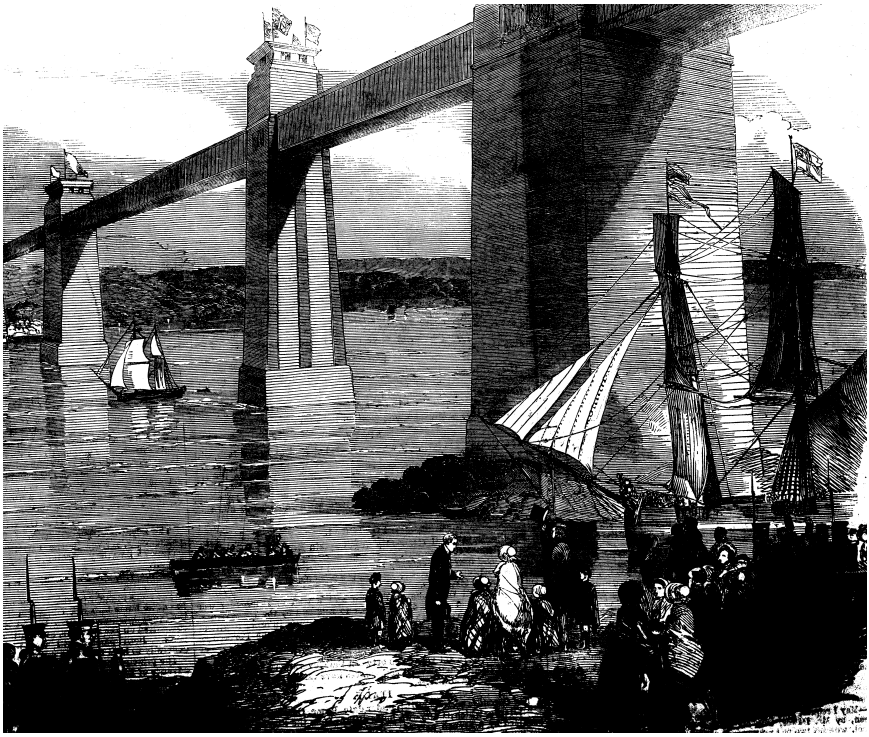

**Figure 4.2** Britannia Bridge, Menai Straits, Wales, 1850. Designed by Robert Stephenson. From *Illustrated London News* 21, 23 October 1852, 329.

suspension bridge, as in Thomas Telford's 1826 crossing of the same strait, was considered insufficiently rigid for heavy rail, and a spate of suspension bridge collapses under induced oscillation (wind, marching soldiers) had made engineers cautious. That eliminated all known methods of building a bridge. Stephenson had to invent a new structural form.

The design concept he chose to investigate was a truss in the shape of a rectangular tube, constructed of riveted wrought-iron plates, large enough for trains to pass through the interior. Such a structure would be unlike anything ever attempted. By 1850, the longest wrought-iron bridge was 31.5 feet. Stephenson's span was 1,500 feet. A 1500–foot-long wrought-iron beam was altogether new to human experience. Wrought iron had never been used on so large a scale. There was no reliable knowledge concerning either the feasibility or the safety of such a structure. Where are the stresses? How thin can the members be? How should

they be joined? Having no answers, Stephenson initiated the most extensive experimental research project in engineering to that time. With no theory to apply, he followed the method of parameter variation, testing shapes and thickness in iron beams at a shipyard. He ran the gamut of plausible shapes for the beam (round, elliptical, rectangular), and systematically explored the relationship between strength, section size, and span.

Engineering the bridge created spin-off knowledge of wide application. As the world's first major use of wrought iron, Britannia Bridge led the way in showing how to make structural members with the new material. Historians of the bridge find it "difficult to conceive how riveted wrought iron could have become the dominant structural material as early as the 1850s, as it did, without the vital information provided by [Stephenson's] bridge-building experience."[23] The new knowledge was promptly applied in other bridges, including works by I. K. Brunel and the massive Forth Bridge (1890). The knowledge also reached beyond bridge design to change methods of construction in building cranes, hydraulic machinery, and ships, including Brunel's *Great Eastern* (1858). Designing Britannia Bridge therefore developed new knowledge by experimental investigations where no theory or science existed.

Francis Bacon thought experimental science might proceed the same way, and created a pernicious myth of inductivism, depicting scientists as innocently collecting facts until a theory falls out. Philosophers of science made a good point in criticizing the myth, insisting that scientific experimentation is never without theoretical presuppositions.[24] Yet this still argues resemblance, not distinction, between the sciences and engineering. In engineering, all the options are technically available, with different costs and benefits. What Duhem, Popper, Quine, and others are saying is that it's the same in science. In Quine's classic formulation, "Any statement can be held true come what may, if we make drastic enough adjustments elsewhere in the system." Any result of any experiment can "be accommodated by any of various alternative reevaluations in various alternative quarters of the total system." It all depends on how much *tinkering* scientists want to do, or their assessment of the costs and benefits of different *technically* available alternatives. "Revision even of the logical law of excluded middle has been proposed as a means of simplifying quantum mechanics."[25]

Most accomplishments in engineering are based on prior engineering. Technological changes tend to come through modifications to existing design, without the epoch-making revolutions that periodically puncture the equilibrium of the sciences. The engineering strata can run deep. For instance, while the internal combustion engine was unimaginable five hundred years ago, the principles of every part (except the electrical components) were known in Leonardo's time, with some (pistons) dating to the first century C.E.. A historian of technology's

evolution says that "every novel artifact has an antecedent. . . . Wherever we encounter an artifact, no matter what its age or provenance, we can be certain that it was modeled on one or more preexisting artifacts."[26] One cannot as confidently say that scientific advance comes primarily from prior science. A characteristic of an advanced technoscientific economy is that problems arising at the technological frontier prime the research agenda of the sciences. Science is less applied than generated by technological production. A historian of science says that "scientific specialities of astounding practical competence, and even entire scientific fields, have been brought into existence by an instrument or a technology."[27] There are celebrated cases, like the steam engine inspiring thermodynamics. The technology of the transistor did not emerge from prior theory in solid-state physics, a subject that was apparently seldom taught in universities until *after* the device was invented. It was the appearance of the new technology that spurred the development of the theoretical field.[28]

The expansion of basic science after the Second World War owes much to a research infrastructure of materials, apparatus, laboratories, communications, instrumentation, and so on, all created by engineers. Richard Feynman is supposed to have said that working desk calculators were as important to the Manhattan Project as the fundamental physics. Philosopher of science Ian Hacking describes the construction of an experimental device named PEGGY II, a polarizing electron gun used to test the hypothesis of elementary particle parity violation. The engineers who made it used no scientific theory of the phenomenon it was supposed to detect, nor is there a theoretical explanation of precisely why the machine they designed works. Yet without their engineering, basic science would have been stymied.[29]

Many instruments developed by private manufacture for basic research later return to new applications in manufacturing. It is probably this recycling that's the boon of science to industry, and not the promised applications of basic research. Instruments taken over by industry are standardized, automated, made more certain and readily available, and even find their way back into sciences where they were not previously employed. The electron microscope is an example. There is also a flow of design and fabrication skills; for instance, micro-fabrication techniques, the ability to design and fabricate structures on a nanometer scale. It was basic research that first felt the need for such skills, but the scientists had to rely on technicians whose training was industrial, and who took what they learned on scientific secondment back to industry.[30]

On the rare occasion when basic research is technologically fruitful, the need for extensive complementary invention may produce long lags between discovery and application. The basic science of lasers was in place by 1916. The rest, which is almost everything, was engineering. The movement from scientific discovery

to technological application is typically one of many initially independent steps. The accidental synthesis of mauve and the discovery of aniline dyes led to the first chemical industry only when combined with economic and geopolitical changes in the availability of traditional colorants. There are special difficulties associated with the step from research lab to industrial production. Manufacture cannot merely scale up processes carried out in a laboratory. The industrial translation of laboratory conditions requires expertise of an entirely different sort. Chemical engineering, which specializes in this translation, is a unique discipline not reducible to "applied chemistry."[31]

It once seemed plausible that "good science" could guide democratic citizens in governing their state. Science would settle controversies incontestably with an objective truth that established the facts. The twenty-first century begins with the understanding that like so many other great ideas of the nineteenth century, this one is hopeless. The sciences have no aptitude for settling political controversy, and that's a good thing too, a victory for democracy over "order" (that is, no democracy). Once a field of research becomes sensitive or prominent (for example, research on global warming, prions, or ozone depletion), the inevitable scientific uncertainties acquire popular and political interest. There are new incentives to take "technical" disagreements public. Additional research may reveal new uncertainties and deepen the controversy. Political debate thus raises the stakes of scientific debate, and political controversy fuels scientific controversy. At the same time, research is not driven by curious minds following their hunches but by funding levels, job opportunities, public expectations, economic interests, and political agendas, all of which are as serendipitous as basic research itself.[32] All of this is not a tertiary accretion around a core of pure science. It is the context of scientific advance as we know it.

## Technological Trash

On the far side of the technological threshold most of what was made at all was made by techniques high in risk. Much artifice was rough, and well-made works were not common. On our side of the threshold, however, more and more of what is made at all is very well made. Any junkyard overflows with artifacts whose construction, parts, and surfaces show artifice of a high order, with regularity, detailing, joining, and tolerances that would amaze a preindustrial artisan, despite what damage may have consigned them to the trash. Think of a plastic drink bottle thoughtlessly dropped in the garbage. It's astonishingly well made—the lightness and transparency of the material; the regularity of the surfaces; the seemingly machined ridges of the screw-top; and the flexibility, strength, and elegant

thinness of the container walls. Or think of a polystyrene fast food container, used for seconds, then trashed. Imagine the astonishment of someone like Leonardo encountering this worthless thing. How was it made? Of what material? How were the colors applied? Whence the exquisite regulation of the workmanship? And how could something this well made be *worthless?*

Leonardo would look at the container through the eyes of a culture whose production was almost entirely the uncertain artifice of skill. In his time, practically nothing was produced with the certainty we routinely extract from industrial automation, and which eventually becomes the best-made trash in history. Not only have we the best-made trash; we have more of it, more trash of all description. Between 1900 and 2000, human population increased fourfold. On average, each one of those new people consumed four times more resources and released four times more waste, raising humanity's impact on the earth by a factor of sixteen in only a century. What does it say about the human prospect when the largest artifactual structure on the planet is a garbage dump (Fresh Kills, Staten Island)?[33]

Over the last five thousand years human trash became predominantly urban trash, and with globalization urban trash is most of the trash there is. Urban trash is industrialized, then technologized, as production merges with technology and science in the twentieth century. Now even trash is high-tech. Walk through urban neighborhoods on garbage day. At curbside you'll see television sets, microwave ovens, daisy-wheel printers, video monitors, even entire computers, not to mention exercise bicycles, now equipped with microchip technology. Any of this may be worn or broken and not worth repair, or merely not wanted. Even broken, the stuff remains exceptionally well made. The detail, precision, joining, materials, machining, and finishes are unique in the stratigraphy of human detritus.

Technological trash is well made because technological artifacts consigned to the trash are mass-produced and made to interface. Suppose you notice a computer circuit board—say, an old modem—in the curbside trash. Someone could conceivably use its parts, though it's usually cheaper to buy new electrical components than to recycle them, something practically impossible with integrated circuits. So the circuit board is trash. Examine the worthless thing. The high level of finish and diversity of materials reveals it as urban, as civilized, as mass-produced. Consider how much of it is designed for connection to other machines. As a modem, it mediates between the telephone line and the computer's central processing unit (CPU). That is a matter, at the level of circuitry, of multiple connections and precise, rapid switching across all contact points, plus careful tuning to standard interface protocols for both the CPU and the telephone line. There is practically nothing about the circuit board that is not technological, in the sense of having been made in anticipation of other machines with which it is coupled.

The density of that coupling is probably what got it trashed. Technically, it works fine. The circuitry is intact; it still does exactly what it was designed to do. It is worthless only because of changes in everything to which it must connect. Technological works are so made in anticipation of other works that they are vulnerable to paralyzing obsolescence well before they fail, fueling the smoldering toxins of the best-made trash in history.

The shift from repair to replacement, especially in consumer goods, contributes to the growth of high-tech trash. I suppose few today would try to repair a seriously malfunctioning television. If it's under warranty, we'll return it, if not, it's probably trash. Yet I remember when *every* television was repaired. Television repairmen came to your home to do it. I remember their fascinating toolbox, whose lid folded out to hold a selection of vacuum tubes. Repair is not necessarily a bad thing to have to do.[34] It is good to live in a world that can be repaired, with works worth repairing. A world where things are badly made is not one in constant need of repair. It's a world where nothing is worth repairing. To repair is to keep at work, to refuse to throw away. Something is trash when it is spent, exhausted, used up. It becomes that way when people no longer know how to use it. Sometimes we even use art and knowledge to build obstacles to such knowledge. What are you supposed to do with the polystyrene container your fast food comes in after you've eaten? Wash it and take it home? The once useful thing in your hand stares back with dull inutility and you look for a place to toss it.

The whole ethics of artifacts is concentrated in the problem of trash. Trashing is something we do to artifacts, and is as consequential as use. In use we care for works, when we trash them we withdraw care. To withdraw care from something for which we are responsible is a moral act, and it is a moral problem because artifacts don't stop needing care just because they can't be used. Even as trash—especially as trash—they require costly care. Things may be spent but still count because they still importune. Kitchen scraps and excrement are "waste" only if they require expensive treatment. If they are instantly recycled in garden compost, they are resources, not trash. The cost of trash is the cost of doing anything with it, even leaving it alone. Anything we do with it has an unrecoverable cost, and we have to do something because doing nothing is making a choice too.

Someone might scoff at my plea for morality in dealings with artifacts. Someone might say that morality is only for humans, in recognition of our intrinsic moral dignity. Since artifacts don't have intrinsic moral dignity it's appropriate to treat them as mere means. I agree that artifacts lack intrinsic dignity, but people do too. A moral dignity exclusively for us would be an unnatural discontinuity, fallaciously setting humanity apart from the rest of living nature. It is an impossible dichotomy on any understanding of evolution. Genealogical continuity links practically every organism on earth. You and the cows in a Big Mac are kin. You

haven't shared an ancestor in several million years, but that's just a number and doesn't support a categorical distinction, as if the suffering of cattle simply couldn't make a moral difference. In a world where everything alive is bound by countless threads of ecological dependence and common descent, species membership carries no moral weight.[35] Dignity belongs to those who have it, and is not a generic human fait accompli.

What we call morality is an elaboration of what Darwin called our social instincts. Like apes, human beings are intensely social primates with similar social proclivities. These include a disposition to sympathy and need for a group we can be loyal to. Most of moral feeling begins there. With experience and understanding, we expand the circle of sympathy and altruism, from clan or tribe to nation, even humanity. We may extend morality to other animals, even trees, even artifacts. We count members of other species primarily because they suffer. But if, like trees or entire species, they do not meaningfully suffer, they may still count, or can be made to count by spokespersons who tie human beings and trees together in a common future. Artifacts are no different. They are not mere means but collaborators, social partners, and they impose themselves; they don't conveniently disappear when we have no more use for them. Instead they become trash, which is always a loss and sometimes a dangerous one.

But isn't it a pathetic fallacy to call an artifact a social partner? After all, artifacts have no good, no *conatus,* no will or interest of their own. Well, not without us! But neither have we without them. Human beings can no more exist without an artifactual economy than without fresh water. Any purpose we pursue is so criss-crossed by artifice that we have no idea of a "good" that wouldn't be artifactually mediated, and even artifactual itself. Artifacts are so much a part of our knowledge, economy, and evolution that we can hardly exclude them as indifferent to moral deliberation, especially in the technological field. Bruno Latour thinks that this "joint historicity of humans and nonhumans" is "the totally unexpected discovery collectively made over two decades by historians and sociologists of science."[36] Waste artifacts like the ozone hole or the still-smoldering nuclear power plant at Chernobyl are nonhuman *players.* They may not have a personality but they have effects that can overwhelm even the best knowledge, and they merit representation in democratic deliberation.

Artifacts are not morally neutral. They are implicated in everything we are. There is no such thing as a neutral means. Once you see artifacts this way, you have to think differently about trash. The common good requires peaceful coexistence with sometimes unruly artifacts. Trash gathers along the fault lines of this coexistence, where artifacts become uncooperative, unworkable, yet still needing care. Trashing is like the end of life. It is inevitable. It is also an ethically sensitive transition we have to negotiate with the nonhumans whose fate entwines our

own. What does morality require in relation to artifacts? I think Latour explains this well. "To maintain the reversibility of foldings is the current form that moral concern takes in its encounter with technology."[37] The reversibility of foldings is, in a word, recycling. We don't just make things, we make things of made things. Every artifact, especially technological artifacts, folds countless others into the black box of its effectiveness. Ideally we can reverse these folds, recovering materials to fold into another assemblage. Trash begins where this reversibility (its art or knowledge) is stymied.

Could there be a trashless economy? Thermodynamics may count against it. There will probably always be trash as there will always be tragedy, since knowledge is always limited. Trash per se is not a problem, though. The problem is its cost, especially the cost of urban, technological trash. With urban density now practically global, trash enters the rank of global ecological agencies. We need to be more technologically inventive about trash so that the technological invention on which we depend doesn't cost so much.

## The Fallacy of Functionality

> The paradox of technology is that it is always praised for its functional utility, or always held in contempt because of its irritating neutrality, although it has never ceased to introduce a history of enfoldings, detours, drifts, openings and translations that abolish the idea of function as much as that of neutrality.
>
> Bruno Latour

*Form follows function*—every word of this inane apothegm contains a mistake. Form does not "follow" from, or is not determined, derived, or entailed by, anything, least of all somebody's idea of function. Devices are not formed for functions. A device has a function only when a person assigns one by enrolling it in a subprogram. That's not what designers design for. They design for the reliable generation of specified results. What "function" those results may have in an application has almost nothing to do with the work's form or shape.

Technical form is not deductive or calculated. It is underdetermined both by instrumental reason ("function") and the way the world works ("physics"). I explained (chapter 2) that there is no "one best way" to design anything, though there's often a cheapest way. We have no idea what a purely functional artifact would look like; no such thing has ever been designed or fabricated. All devices of the best design do unwanted, useless, even counterproductive work (engines get hot, lights attract bugs); and practically anything we make owes some of its qualities to useless, easily avoidable work on appearance (smooth door panels, polished metal, regular fastenings, and so on). Useless work for

appearance (art) is a deep pattern of human artifice at least since the late Paleolithic.

If form should follow function, why don't seriously functional artifacts like aircraft, ships, or bridges look more alike? What is the function of a bridge? Let us say, stability under a load conveying traffic over a barrier. Anything that does that is a bridge, and the form that functions most efficiently is the best, most rational, technically correct one. Fine. Now, in order to fulfil this "function" the bridge must resist the forces to which it is predictably subject, forces that would pull it down or twist it. But exactly what are these forces? Where do they act? How do they combine and resolve? You can hardly make a bridge that deals efficiently with forces unless you know where they act and their magnitude. Don't think science has the answer—that engineers can consult a scientific theory for equations to calculate the force to which a structure is subject. Nothing remotely like that happens or is even possible.

A designer does not first consider a bridge's function and then devise a structure appropriate to calculated forces. Instead, choosing a structure *determines* what forces its parts are subject to. The same load generates entirely different profiles of force depending on the structure. Consider some common structural forms (figure 4.3):

(a) A beam suspended at two ends, like a lintel over columns, or a tree trunk over a stream. A load at midpoint bends the beam, generating a compressive force across the upper portion and a tensile force across the lower part. Should it fail, the cause will be horizontal sheer where these two opposite forces meet.

(b) The same load on a truss. The system of triangles creates a rigid structure; it cannot deform. This geometrically induced rigidity converts the load to purely vertical compression acting at the two ends, where it is transferred to the foundations.

(c) In a suspension system, the load generates tension in the cables (transferred to anchorages) and compression on the towers, which are glorified wedges jacked under the cables to create the elegant catenary droop.

(d) In a Roman or semicircular arch, load converts to a lateral thrust pushing the masonry voussoirs against each other, channeling the force down to the foundation. Besides the vertical (compressive) force taken by the foundations there is an oblique lateral thrust that will flatten the arch unless it is retained by buttresses. That's what Eduardo Torroja is thinking of when he calls an arch "a jugglery with structural functions that are passed to elements external to the structure proper."[38]

(e) The genius of the pointed, or Gothic, arch is that a simple modification of geometry—this form is two semicircular arches on their sides—eliminates the horizontal kick of the Roman form, leaving vertical compression as the only structural

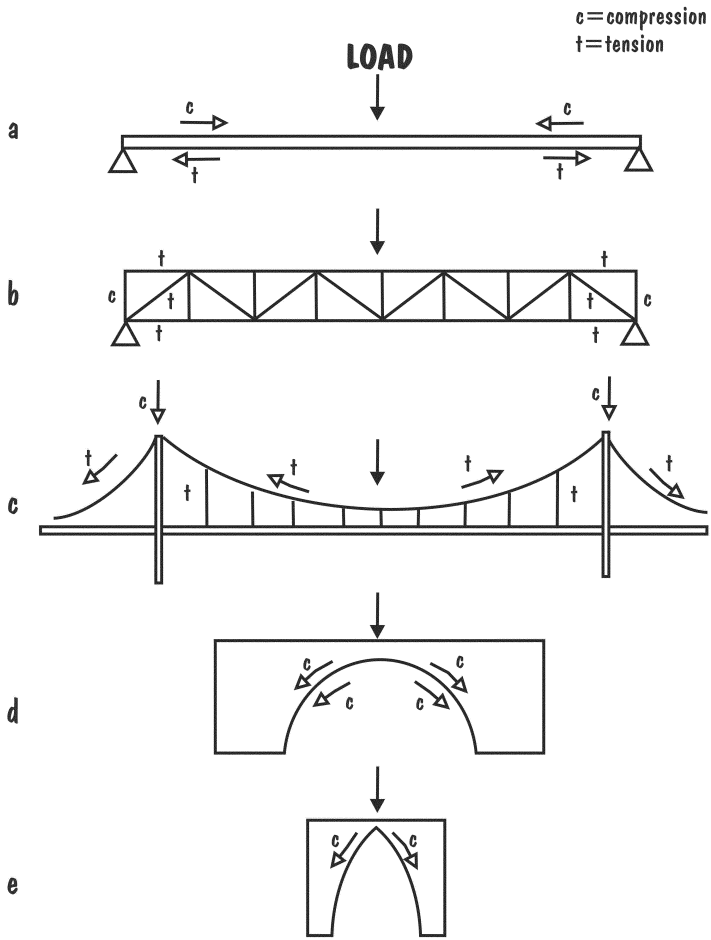


**Figure 4.3** Common Structural Forms: (a) beam, (b) truss, (c) suspension, (d) Roman arch, (e) pointed arch. Reprinted with permission from *Common Knowledge* 12 (2006): 362.

> force, which the new arch carries straight down to the foundations. The twelfth-century shift in European construction from Romanesque to Gothic was more than a change of symbolism. The new arch makes walls structurally superfluous. For the first time, European engineering surpassed the Romans.[39]

What vectors of force a load generates depends on the structure, which depends on the designer's choice. It is not the function of the form to respond to potentially destructive forces, to meet them and stand up. There is no saying what

**Figure 4.4** George Washington Bridge, Hudson River, New York City (looking northwest from the city), 1931. Designed by Othmar H. Ammann. Library of Congress, Prints & Photographs Division, Historic American Engineering Record, HAER NY, 31–NEYO, 161-13.

those forces are until the bridge is designed, and even after it has been built and passed into service theory may remain mute and uncomprehending. The form not only controls but actually generates the forces to which it is subject. The greatest source of load in a bridge is simply its own dead weight. Its "function" (what it has to do) is just to hold itself up—the live traffic load is insignificant. For example, New York's George Washington Bridge uses a suspension system whose cables and deck alone (not including the towers) weigh five times the heaviest potential live load (figure 4.4).[40]

Science never tells an engineer how to put anything together. There is never one logical, rational, calculable, supremely functional way to make anything. Any device could have been made differently from different parts and still worked (technically if not economically). That is why not all bridges look the same, and why their differences cannot be dismissed as subjective, or arbitrary social representation. There is no purely technical rationality and no purely functional artifact. The appearance of inevitability in technology (couldn't have been done another way, form follows function, inevitable progress) is an illusion to which contemplative nonpractitioners especially are susceptible.

Since there is no one best way to make anything technically complicated; since engineering thrives on alternatives and causes options to proliferate—options a

designer cannot negotiate on mathematical autopilot but must treat with judgment, taste, and style—then technological design is evidently more like composing and performing a symphony than solving an equation, and perception, the aesthetic interface, belongs to the *technical* conditions of the best work in engineering.

## Engineering Art

> It is a crime to build an ugly bridge.
>
> Othmar H. Ammann

That aesthetic design (design for perception) is integral to engineering is amply attested by reflective practitioners.[41] Among the greatest, Gustave Eiffel, writing in the Paris daily *Le Temps* in 1887, in reply to controversy over his tower, then under construction:

> Because we are engineers, do you think we are not concerned with beauty in our constructions and that when we strive for solidity and durability, we do not also strive for elegance? Do not actual conditions of strength always conform to the secret conditions of harmony? The first principle of architectural aesthetics is that the essential lines of a monument be determined by their perfect appropriateness to their intent. What conditions have I had, above all, to take into account for my tower? Wind resistance. Well, I claim that the curves in the four ridges in my building, as supplied by my calculations, will give an impression of beauty, for they will translate to the eyes the boldness of my conception.[42]

Early in his career, the Swiss-American bridge designer Othmar Ammann (1879–1965), who would later design some of the greatest bridges in the New York region, served as First Assistant on Gustav Lindenthal's famous Hell Gate Bridge (1917) (figure 4.5). Writing in his technical report for the American Society of Civil Engineers, Ammann describes it as "one of the finest creations of engineering art of great size which this century has produced." "A great bridge in a great city, although primarily utilitarian in its purpose, should nevertheless be a work of art to which Science lends its aid. . . . It is only with a broad sense for beauty and harmony, coupled with wide experience in the scientific and technical field, that a monumental bridge can be created." Thirty years and half a dozen major bridges later, Ammann felt the same way. "Mere size and proportion are not the outstanding merit of a bridge; a bridge should be handed down to posterity as a truly monumental structure which will cast credit on the aesthetic sense of present generations."[43]

To mention one more reflective practitioner, Felix Candela, a highly accomplished designer of thin-shell concrete structures, says: "Beauty has no price tag

**Figure 4.5** Hell Gate Bridge, East River, New York City, 1917. Designed by Gustav Lindenthal. Library of Congress, Prints & Photographs Division, Historic American Engineering Record, HAER NY, 31–NEYO, 167-11.

and there is never one single solution to an engineering problem. Therefore it is always possible to modify the whole or the parts until the ugliness disappears."[44] That, I think, touches the heart of the matter, which is the availability and necessity of choice. Engineering is pervaded by choice. There are alternative ways to design any component of any system, with systematic implications for the rest of the design. Every technological problem has alternative solutions, and the more engineering there is, the more alternatives to choose from. One might even say that modern engineering does not exist until there is a relative density of technical alternatives and an art of technological choice.

An engineer says, "Engineering design is essentially a matter of thinking of a number of alternative solutions to each problem." Concurring that technical design is "a sequence of comparative choices," another says, "there can be no optimum in structures, but only many reasonable choices." The "function" or

intended result of a device or structure leaves the design problem ("form") practically wide open, as a third engineer observes of bridge design: "Almost every conceivable way in which a bridge could possibly be made has actually been tried, at one time or another, for making real bridges. One might have supposed that one approach to the problem would have turned out to be the 'best' of all and would have come to be generally accepted, but this is not the case; and the number of structural systems which are in common use seems to increase as time goes on."[45]

Two examples from bridge design suggest the scale of engineering choice. In planning the Hell Gate Bridge, Lindenthal's team developed designs for several different bridges at the site, making detailed comparisons among such different forms as cantilever, suspension, and continuous truss, as well as three different arches. Ammann reports "little if any difference in cost between the several types mentioned" and says that the form eventually selected, called a spandrel arch, was favored for appearance. Planning generated a wide range of choice among designs, any one of which would "work" and all at about the same price. The more choices Lindenthal had, the freer his hand to take more and more into consideration, widening the design problem into the realm of public art.[46]

To shift from this grand scale to the minute but realistic, in a 1940 article on "Present Trends in Structural Design" Ammann surveys the options for putting a floor on the deck of a bridge:

> There is a very definite trend toward the use of light-weight bridge floors as a means of effecting economies in the entire bridge structure. Many types of such floors are now available, including steel plate floors, usually with a surfacing material; floors of interlocked steel panels with fillers and a surfacing material; composite steel grid and concrete floors; open grating steel floors; light concrete slab construction; and aluminum alloy types.

The proliferation of technical choice makes design's aesthetic moment prominent:

> The more thorough knowledge of the character and actual behavior of structures has led to greater confidence and freedom on the part of the designer. He is encouraged to depart from conventional practice and to try uncommon forms and types. In this process he has been aided by the growing demand for consideration of aesthetics in structural design, and he has found that this demand is not in conflict with a broad interpretation of the technical and economic requirements.[47]

Engineering's dependence on alternatives generates engineering alternatives, in a self-advancing technological ratchet. The more engineering we do, the more

technological choices there are, and the greater (at least potentially) design's freedom to be art. No economic calculation, no measure of technical efficiency, relieves the engineer of the need to anticipate and design for perception.

For another view of the aesthetics in technics consider what are called statically indeterminate structures. These are structures for which it is not possible to calculate internal stresses and breaking points; the conditions of their equilibrium (why they don't collapse) are unknown. Even computer-assisted calculations are imprecise and incomplete. That hasn't stopped engineers from designing and building such structures. Indeed, much notable structural engineering of modern times has built indeterminate structures. It is science that hasn't caught up with what engineering accomplishes, not engineering groping blindly for want of a theory.

One reason there are more indeterminate structures than ever is because we build so much with reinforced concrete. This material, which first came into modern use after 1894, is cement and aggregate laced with embedded steel, either as rods or wire mesh. The advantage of the combination is that concrete is strong in compression but weak in tension, while steel is the opposite. By a wonderful contingency, materials this different have a similar coefficient of expansion, tending to change size with temperature at the same rate. That allows them to work together; otherwise thermal forces in the combined material would tear it apart. Instead, the strength of each compensates for the weakness of the other. It's not surprising, then, that reinforced concrete has been described as "technically the most nearly perfect material," and "the most fertile, ductile, and complete construction process that mankind has yet found."[48] This material is an artificial stone which, while preserving the inherent (compressive) strength of stone is produced in a semifluid state that can be molded to any shape and does something no stone can do—resist force in tension, force trying to pull it apart.

The material also stubbornly resists mathematical analysis. Apart from the simplest cases long transcended in practice, it is not possible to calculate that a given form in reinforced concrete will have the strength required for a given application. The difficulty is that the compound material doesn't follow what engineers call Hooke's Law. There is no proportion between stress and deformation.[49] That makes the play of forces in a structure of reinforced concrete what an engineering professor calls "mere guesses—even when computed following the most rigorous formulations of theoretical mechanics."[50]

Pier Luigi Nervi, master of the thin-shell concrete dome, says reinforced concrete "presents hidden deficiencies and specific characteristics which make its structural behavior difficult, if not altogether impossible, to foresee exactly. Its high thermal sensitivity, its shrinkage, and above all its plasticity . . . shatter our hope of investigating or knowing either before or after construction the real conditions of equilibrium of any statically indeterminate structure."[51] Candela con-

**Figure 4.6** Brooklyn Bridge, East River, New York City, 1883. Designed by John Roebling. Library of Congress, Prints & Photographs Division, Historic American Engineering Record, HAER NY, 31–NEYO, 90-23.

curs and generalizes: "All calculations, no matter how sophisticated and complex, cannot be more than rough approximations of the natural phenomena they try to represent. . . . There is not such a thing as an exact method of structural analysis and, notwithstanding the popular belief in the letter of the codes, the accuracy of any calculation is still a question of personal judgment"—an observation that the engineering professor says "summarizes the view of every great structural designer from [Thomas] Telford on."[52]

A prominent example of an indeterminate structure is New York's Brooklyn Bridge (1883) (figure 4.6). Here indeterminacy arises not from reinforced concrete (which is not used) but from sheer Daedalian design. Ammann, who describes Brooklyn Bridge as "the most fascinating and outstanding structure of its kind,"[53] writes of the radical indeterminacy quite deliberately introduced into the suspension system by designer John Roebling:

> The system adopted for the Brooklyn Bridge is an extremely complex and highly indeterminate one, so that it is impossible even today to determine the stresses with any degree of accuracy. . . . The stiffening system is a complex combination of trusses along the floor and diagonal stay ropes attached to the tops of the towers. The

> latter, together with the trusses, which are also fixed to the towers, form cantilever arms and thus relieve in part the loads carried by the cables. The interaction between cables, stays and trusses is thus very uncertain.[54]

Far from being technically objectionable, Roebling's system, though complex, is very good engineering. It is also responsible for the beautiful pattern in the cables radiating from the towers, which is unlike most suspension bridges, being visibly more intricate and weblike. The point of the complexities Ammann describes is to prevent the bridge deck from beginning to sway in the wind. Roebling's design dampens wind-induced oscillation with geometry rather than brute stiffening, protecting the deck from probably its primary structural danger (it was wind-induced twisting that tore down the Tacoma Narrows suspension bridge in 1940), without adding the weight, cost, and unsightly bulk of rigid stiffeners along the length of the deck.

The nimbus of theoretical uncertainty surrounding indeterminate structures has not deterred engineers from designing them. Yet how can one make a rational choice among forms whose stresses and breaking points are incalculable? Let's look at how Swiss engineer Robert Maillart (1872–1940) dealt with the problem. Maillart was probably the outstanding structural artist of the twentieth century. His works take structural indeterminacy into the stratosphere. The essential idea is to use the monolithic qualities of reinforced concrete to advantage. Every part becomes an integral structural member, molded into one elegantly shaped monolithic stone. In a Maillart warehouse, columns are one form with the slabs they support, eliminating the need for joists and beams in a floor. In a Maillart bridge, the deck is not merely supported by the arch; it is an integral structural member of it. Instead of a dead weight carried by the arch, the road deck is built-in and contrived to make the arch stronger, hence thinner. His bridge at Valtschielbach (1925) (figure 4.7), a 43-meter arch, is 23 centimeters thick at the crown and 29 centimeters at the supports. And thinner means less material, hence less expensive to build. Most of Maillart's bridges were competitively bid, and the work never failed, with 45 of 47 career bridges still in service (1997).[55]

Maillart was convinced that reliance on theoretical calculations was an insidious danger in engineering. His solution to the incalculability of stresses in his material was to design forms in which the flow of forces was easily visualized, and then subject them to full-scale tests.[56] Before you can perform a test, though, something worth testing has to be designed. The marvel of a Maillart design is how structural innovation merges with aesthetic accomplishment. Contriving to make the flow of forces conspicuous made a visually fascinating form. For Maillart, aesthetic thinking about looks is a critical moment of technical thinking about

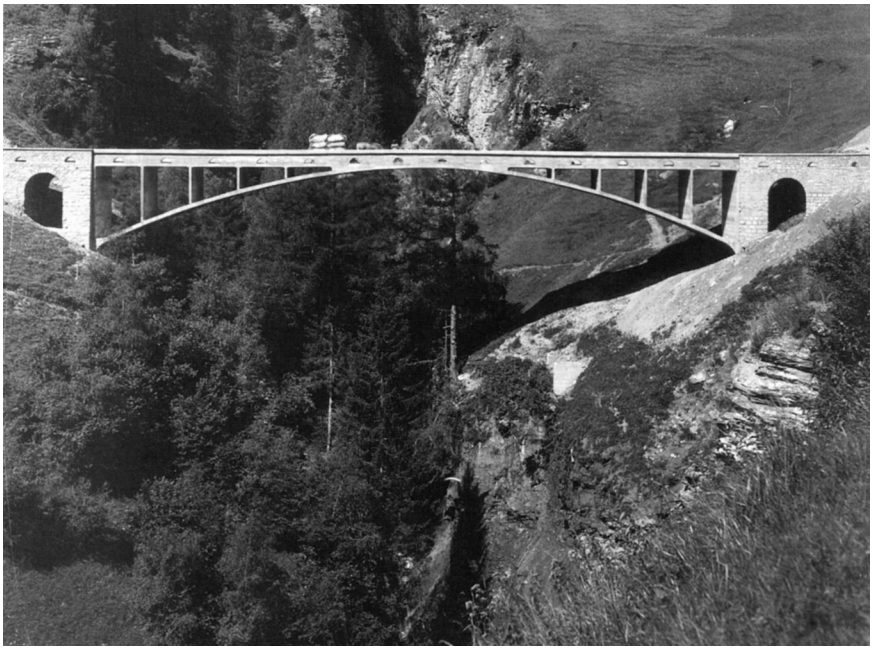

**Figure 4.7** Valtschielbach Bridge, Donath, Switzerland, 1925. Designed by Robert Maillart. From David P. Billington, *Robert Maillart: Builder, Designer, and Artist* (Cambridge: Cambridge University Press, 1997), figure 143, p. 180.

static equilibrium. What makes the bridge work structurally makes it work aesthetically and vice versa. "He never separated his technical arguments from his aesthetic ones," says Maillart's engineer-biographer. "He sought one solution to both problems."[57]

## Two Bridges

> Aesthetics, however much it depends on subjective personality, is nevertheless intimately linked to the geometric, analytic, mechanical, and strength properties pertaining to surfaces and lines that limit the masses of a structure.
>
> Eduardo Torroja, *The Philosophy of Structures*

Let's look again at the interaction of aesthetics and technics, this time in the design of two bridges. One I already mentioned, Lindenthal's Hell Gate Bridge (1917) (figure 4.5). This is a railway bridge carrying four sets of tracks over New

**Figure 4.8** Bayonne Bridge, Kill van Kull, Bayonne, N.J./Staten Island, N.Y., 1931. Designed by Othmar H. Ammann. Library of Congress, Prints & Photographs Division, Historic American Engineering Record, HAER NJ, 9–BAYO, 1-18.

York's East River. Its span, 977 feet, set a world record when built. The second bridge is Ammann's Bayonne Bridge (1931), linking Bayonne, New Jersey with Staten Island (figures 4.8–4.9). Its 1,675-foot span also set the record on opening.[58] Technically, both bridges are arches composed of a parabolic steel truss, and loaded from below by a suspended deck rather than over the crown. By making the arch parabolic (rather than semicircular), and building it from a steel truss (rather than stone blocks), the oblique thrust usually taken by massive abutments is eliminated. The rigid truss ensures that loads resolve entirely into two moments of purely vertical compression at either end.

A structure like that encounters two visual problems. First, the upper chord of the truss is for stiffening only and doesn't carry the load per se—it makes the load-bearing lower chord stiffer. That means the business of the upper chord is concluded at the point where the lower chord transfers its load vertically into the foundations. At that point the upper chord can just stop and hang in mid-air. That's what it does in Ammann's bridge. Lindenthal's does the same thing except it's masked (from most views) by the towers (the upper chord does not actually penetrate the tower wall but stops just short of it). Gustav Eiffel found a different solution for his Garabit Viaduct (1884), a so-called crescent arch whose upper and lower chords gracefully meet at the foundation. Lindenthal specifically considered a crescent arch and rejected it for his project. It lacked appropriate vi-

**Figure 4.9** Bayonne Bridge, Kill van Kull, Bayonne, N.J./Staten Island, N.Y., 1931. Designed by Othmar H. Ammann. Library of Congress, Prints & Photographs Division, Historic American Engineering Record, HAER NJ, 9–BAYO, 1-1.

sual expressiveness, as Ammann explains. "The spandrel arch, owing to its height increasing from the center toward the ends, is more expressive of rigidity than the crescent arch."[59]

Should the retiring upper chord visibly hang in mid-air, or not? That's one visual problem. The other concerns Lindenthal's towers, which do more than mask the upper chord's abrupt termination. They create the appearance of receiving and supporting the whole arch, though the effect is purely visual. The towers carry no load. Ammann's bridge proves that. The load on both bridges resolves in much the same way into vertical compression at the ends. That left Ammann free to omit the towers, while nearly doubling the length. Despite being 700 feet longer, Ammann's bridge weighs 40 percent less. Part of the lightness comes from the material, a manganese steel that imparts a lustrous sheen. The alloy is stronger by weight than usual steels and won't rust, but manganese steel

is expensive, and a big bridge like this one uses a lot of it. That's one incentive for lightness, and here Ammann was masterful. His bridge uses 37 million pounds of steel compared to 87.8 million pounds for Hell Gate with only 30 percent of his span.[60]

The absence of monumentally superfluous piers in Ammann's bridge is not a triumph of functional rationality. Ammann's approved design specified monumental stonework over the foundations of the arch. A design was created by the office of Cass Gilbert, architect of New York's Woolworth Building (1913). The indifferent box frame visible around the ends (figure 4.9) was built to hold masonry cladding. Speaking at the opening ceremony Ammann said, "The huge abutments of the arch, which are yet exposed in their crude construction, are eventually to be marked by massive pylons, and will thus further enhance the appearance of the structure in its setting in the landscape." Despite completing the bridge on time and 14 percent under budget, the Port Authority never took action on the pylons and never dismantled the boxy armature designed to hold the stone. Ironically, Ammann had earlier praised the Authority's commissioners: "The Port Authority recognized the fact that its structures must not only be useful, but they must also conform to the aesthetic sense. This was one of the motives for the selection of an arch spanning the entire river in one sweeping graceful curve."[61]

Engineering professor David Billington calls Lindenthal's "reliance on masonry for monumentality" an irrational inheritance from before the Industrial Revolution. "When a designer builds nonfunctional stone towers to visually contain arch forces, which do not in fact exist where they appear to exist, then the design is not an indissoluble union of structure and form but rather a massive frill."[62] Worse than a frill, one so persuaded might say. There's something mendacious about the towers. They tell us, as it were, *we're holding up this great arch,* when in reality they do nothing at all. The towers are all talk, and what they say is untrue—ornamentation of the worst sort.

That was not the view of Lindenthal's peers in the American Society of Civil Engineers, who tended to think well of the design, towers included. Senior engineers invited to comment on Ammann's technical report were undivided in their praise. One called Lindenthal's bridge "the largest, most scientific, and, it is believed, the most artistic bridge yet constructed." Commenting specifically on the towers, another finds them "plain and simple in design, but in every way appropriate and in harmony with the great arch. . . . The whole structure may be said to be the most complete lesson in bridge aesthetics in America, and one of the best in the world." A generation later, Carl Condit, an authority on American engineering, writes of "the power and dignity" of Lindenthal's form. "The slender arch rib, with its massive but simply articulated stiffening truss [the upper chord],

is the very expression of combined stability and energy; its enormous thrust is perfectly contained, in a visual sense, by the heavy masonry towers."[63] The most eloquent defense of Lindenthal's design comes from Ammann himself, writing in his report to the American Civil Engineers:

> Mr. Lindenthal conceived the bridge as a monumental portal for the steamers which enter New York Harbor from Long Island Sound. He also realized that this bridge, forming a conspicuous object which can be seen from both shores of the river and from almost every elevated point of the city, and will be observed daily by thousands of passengers, should be an impressive structure. The arch, flanked by massive masonry towers, was most favorably adapted to that purpose. . . . The massive masonry towers which flank the steel arch greatly enhance the appearance of the bridge and give it its monumental character. They also give expression to the solidity of the abutments to resist the great thrust of the arch. Without the towers, the statically trained eye would want that expression of stability, because of the comparative flatness of the shores.[64]

Ammann defends the towers as a visual need for the *trained* (that is, engineer's) eye. One of his commentators thought it went the other way, that the *untrained* eye feels the want of a visual counterpart to the thrust inconspicuously channeled to the foundations. "It is desirable to make a structure appear not only graceful but satisfyingly stable to the miscellaneous eye as well as to the trained and understanding scientific eye." They are both right. This is the second visual problem I mentioned, a *visual need* for a *visual* force vertically over the arch's foundations. It is a perceptual need, not a structural one, but one to which a response is, Ammann says, "an architectural necessity."[65]

He goes on to imply that the towers are not altogether nonstructural. He says their "static requirement" "is not merely an apparent one"; in other words, they do structural work. Of course these towers, structural or not, are heavy. Combined, and including their foundations, they contain 110,000 cubic yards of cement. It is those foundations, remember, that do the work the towers *seem* to, receiving the thrust of the load. The structural situation is like this: The weight of the deck loads the arch, whose rigid truss channels the force into a compressive thrust at either end. The foundations obviously must be strong enough to carry this load to bedrock. The thicker they are, the more expensive to build. It would therefore be desirable to minimize their volume without sacrificing strength.

The situation is structurally similar to one that arose in medieval European building after the eleventh century. This architecture is famous for two qualities—the soaring height of its enclosed spaces, and the intricately ribbed vaults for ceilings over those heights. Ceilings had never been so high or so heavy, for of

course those elegant vaults are made entirely of stone. A heavy weight from a great height is a tricky thing to support on relatively slim piers embedded in a relatively unstressed wall. The higher ceilings got, the more precarious. Hence, another notable quality of this architecture, the flying buttress, an arch boosted against the outer surface of the piers supporting the vaulting. The design inspired Nervi's appreciative remark that these builders "were the real forerunners of modern technology, replacing the equilibrium achieved by heavy masses of masonry with the equilibrium of forces created by the interplay of thrust and counterthrust of slender ribs built with very good materials."[66]

In a flying buttress, one end of an arch is loaded by the pier it abuts. The buttress then has to convey that force to its own foundation, usually down a column under the springing of its arch. To get that column as thin as possible these architect-masons made a sophisticated reading of the forces in the buttress and an innovative application of what engineers call the Rule of the Middle Third. "The basic condition for the safety of masonry," writes an engineer, "is that the thrust line should always be kept well inside the surface of a wall or column." How far is "well inside"? The traditional rule is to keep the line of thrust in the middle third of the width of the wall or column. The Gothic architects realized that by adding more weight to the top, they could make the column stronger and therefore slimmer, with the added weight serving to more precisely channel thrusts to the middle third. "Contrary to what one might suppose, weight at the top is likely to make a wall more, not less, stable and will bring an erring thrust line back, more or less, to where it ought to be"—namely, within the middle third.[67] That is why the far end of a flying buttress, where the arch transfers its load to an external column, is festooned with stone pinnacles and statuary. They do structural work. Remove them and the buttress no longer responds as designed and may fail.

I go into this because Ammann offers the same defense of the Hell Gate towers. He doesn't make the comparison to cathedral statuary but the structural situation is analogous. By adding weight to the bridge's foundation, which is in effect a column down to bedrock receiving the compressive thrust of the arch's truss, the towers permit the designer to minimize the volume of the foundation while keeping thrusts within the safety zone of the middle third. In his report Ammann twice claims that the towers are structural in this way. The first time he says: "With their great weight, they steepen the resultant arch thrust and thereby limit the size of the deep foundations to a minimum." Later he reiterates and invokes the Rule of the Middle Third. "To restrict the size of the foundations to a minimum, it was necessary to provide above the ground a mass of masonry, the weight of which, combined with the inclined reaction of the arch, would give a steep resultant, passing well within the middle third of the foundation area, so

that the edge pressure could be kept within permissible limits"—like pinnacles atop a flying buttress.[68]

Among the peers invited to comment on Ammann's report was Leon Moisseiff, future designer of the notorious Tacoma Narrows Bridge. Moisseiff questions this structural justification for the towers. He notes less than ideal ground conditions at one abutment, which might have required foundations of unwieldy dimensions. But he says it is not serious to suggest that as a technical justification for the towers. In reply, Ammann says that he "agrees with Mr. Moisseiff"

> that the towers are not an economic feature if intended for the exclusive purpose of keeping the resultant reaction within the middle third of the foundation area, because, if it is a mere question of a sufficient weight of masonry, such weight can be provided more cheaply by extending the foundation in the direction of the axis of the bridge. Where it is a question of providing towers for architectural reasons, however, such towers constitute at the same time a considerable saving in the foundation masonry and are then not entirely for architectural purposes.[69]

Fifteen years later, reporting on the construction of his George Washington Bridge, Ammann returned to the question of this "architectural necessity." The case is again ironic. The towers of the George Washington Bridge as we have it (figure 4.4) comprise a complex high-tech web of exposed structural steel. That wasn't the idea, as it wasn't Ammann's idea to leave the abutments of the Bayonne Bridge without a visually forceful response in stone. The towers were supposed to be clad in concrete and faced in granite. Ammann was surprised at the agreeable appearance without cladding, finding the exposed steel to "lend the entire structure a much more satisfactory appearance than [I] (and perhaps any one connected with the design) had anticipated." Nevertheless, he says, "the appearance of the towers would be materially enhanced by an encasement with an architectural treatment."[70]

It's true that Lindenthal's towers do no important structural work. Instead, they do important visual work, perceptual work, aesthetic work, and there's nothing mendacious about them. Their work doesn't make the bridge stronger. It makes it look like it has the strength it does have. The massive arch creates a visual need for equilibrium in the form of a vertical visual mark where it touches the earth. This visual need is not premised on the fallacious assumption that a parabolic truss behaves like a masonry arch. Neither is it a barbarous desire for gaudy ornament appended to a rational structure. It has nothing to do with structural forces right or wrong.

A good bridge works on two levels: statically, resisting forces that would pull it down or twist it; and aesthetically, perceptually, its visual appeal. The design problem is greater than that of static equilibrium at lowest possible cost. To limit

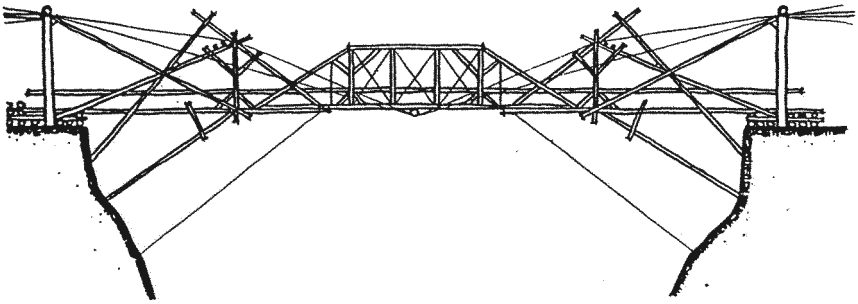

**Figure 4.10** Kwakiutl bridge over Bulkley River, Ahwillgate (Hagwelget), British Columbia, circa 1868. Two hundred feet above the river, this bridge is an entirely native design and construction, with a clear span of 150 feet. From J. A. L. Waddell, *Bridge Engineering* (New York: Wiley, 1916), p. 5, figure 1d.

design that way makes the engineering problem simpler than it properly is, and offloads long-term costs to the community that has to live with incomplete work. The need for such conspicuous artifacts as bridges to work both visually and statically makes the design problem simultaneously aesthetic and structural. Indeed, the requirement of visual work is a technical problem that can only be addressed effectively by an aesthetically nuanced response.

It is possible for a bridge to be in static equilibrium, quite safe from a structural point of view, and yet to lack, even profoundly lack, visual stability, as a bridge at Hagwelget, British Columbia, dramatically demonstrates (figure 4.10). It takes a trained eye to look at a complex structure and see its conditions of static equilibrium. But that doesn't mean that when untrained eyes look at structures people make mistakes and form false beliefs about those same engineering conditions. An engineer has *learned* that there are directed physical forces like compression, tension, and torque, and that their treatment is crucial to the stability of a structure. Without such training, most people don't concern themselves with static equilibrium, as engineers must. They are, however, spontaneously concerned with the visual, psychological equilibrium *of their perception,* which depends on principles other than engineering statics.

I discussed (chapter 3) the expressiveness of visual perception, how this perception is dynamic, animating shapes and colors with tension and tendency. We see not shapes or lines but dynamic shapes and expressive lines, solids pregnant with movement. Rudolf Arnheim says, "The very percept of [a] bridge, in order to be complete and correct, must include the presence of the absent bridge-crosser. Otherwise it is an enigmatic ornament."[71] I think he's saying that to see a stable bridge and not an enigma requires a *perceptual* equilibrium, an equilibrium of

*visual,* not static, physical forces. For a bridge like Hell Gate, where the arch is notably expressive of heaviness, to see the form equitably requires a visual vertical reply where the arch meets the earth. It is a visual requirement, not a structural one, but a response to it satisfies human need as much as do accessibility and static equilibrium.

Reverting to the planned encasement of the George Washington Bridge towers, Ammann mentions the predictable objection that by covering their structural steel he would "camouflage" their "true structure and its function." He is unimpressed by the argument:

> The covering of the steel frames does not alter or deny their purpose any more than the exterior walls and architectural trimmings destroy the function of the hidden steel skeleton of a modern skyscraper, except to the uninitiated. Camouflage in this sense would condemn many of the creations in private and public life. It is an essential manifestation of civilization and is not incompatible with sincerity and honesty of endeavor, because an essential part of human effort is to create an aesthetic atmosphere, the value of which cannot be expressed in economic terms. . . . Why should not a supreme effort be made in that respect in engineering structures, especially those that are viewed daily by thousands or millions of people?[72]

"Economy and utility are not the engineer's only concerns," he reiterated twenty-five years later. "He must temper his practicality with aesthetic sensitivity. His structures should please the eye. In fact, an engineer designing a bridge is justified in using a more expensive design for beauty's sake alone. After all, many people will have to look at the bridge for the rest of their lives."[73] One has to be pretty crass not to think he has a point, but it matters what point we think it is. Several of the engineers who discussed Lindenthal's design claim that technically untrained people see the towers as required to receive the (nonexistent) oblique thrust of the arch. Supposedly they don't know about trusses or structural rigidity and still see as Romans did.

I don't buy that. I don't imagine Lindenthal's towers saying, as it were, "I know that you, technical illiterate, think some prodigious mass must receive the weight of my arch, but that is false, as I, being scientific, know. Yet I shall cater to your vulgar error, and give you something big and powerful where you think you need it." Instead, I imagine Lindenthal himself, as designer and citizen, saying to his public: "When we see a forceful horizontal shape like my arch, we see that it is very heavy, very horizontal, and very suspended over thin air. We see, too, that it's thicker at the ends than at the top. That creates a visual need for an equilibriating vertical moment, which my towers provide." What is acknowledged by the towers is not a false belief of the ignorant about static equilibrium. It is a true belief of anyone about visual equilibrium, and good engineering must take it into account.

Why isn't static work enough? Why should a client care about visual, aesthetic work? The question really belongs to the designer rather than the client, because if designers are compelled to care, then clients will just have to pay for it. One reason is workmanship. The respectability of their profession requires designers to care about the quality of their work, and that means caring about the look of it, its aesthetic relationship to the site, the public, and a history of artifacts. It is not a designer's professional responsibility to give a client the cheapest possible work. The responsibility is to give good work at competitive rates, and good work, good engineering, often requires a design that works aesthetically as well as statically. Another reason to care about looks is for morale. A bridge that only works statically is like a table that only stands up, or a hovel that shelters without comfort. It's like serving guests tinned meat and powdered milk. Yes, it's food, but tasteless, brutal, indifferent to the feelings of others. A bridge that is merely stable is like food that merely nourishes. Neither makes us want to come back. Neither gives us anything to live for. What's missing? Isn't it simply the good taste of art?

We have examples of such ethically dubious engineering in what are called the aesthetically notorious bridges. A consulting engineer in bridge design undertook a study of a century's worth of English-language commentary on bridges. His research team identified and collated material from all published sources, professional and popular. They found practically all criticism to concentrate on the same five bridges—one in Pakistan, two in London, and two in New York. These are the "aesthetically notorious bridges." You may recall from chapter 3 that some philosophers doubt whether anything is *invincibly* ugly. These bridges challenge their optimism. While there are differences in what critics select for negative comment, there is almost invariably agreement among professionals and nonprofessionals that these bridges are *ugly*.[74]

Let me briefly discuss one of them, the Lansdowne Bridge (1889) over the Indus River, in present-day Pakistan (figure 4.11). On opening it was the longest cantilever span in the world (250 meters), a record held for one glorious year until the Forth Bridge (518 meters) opened in 1890. There is a lot of agreement that Lansdowne Bridge is an aesthetic catastrophe. One engineer-critic deplores the "irregular shapeless profile, the derrick-like appearance of the cantilever arms, and the mean character of the suspended span."[75] But there is an instructive divergence in the reasons critics give for why the bridge is bad. One kind of critic exalts the bridge's supposedly scientific functionality, which is turned against engineering as proof that science and functionality are soulless and spiritually inadequate. "It would seem that any structure designed on lines of true economy, with the utmost simplicity and the lowest number of parts, was a beautiful thing. Yet such [a design] as the [Lansdowne Bridge is] irredeemably ugly." This argument obviously assumes that the

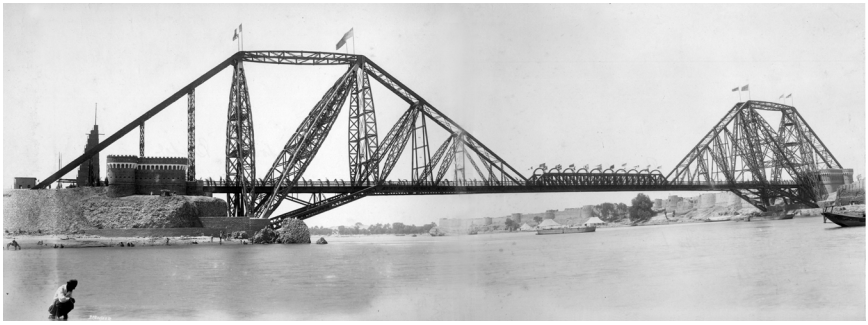

**Figure 4.11** Lansdowne Bridge on the Indus at Sukkur, Pakistan, 1889. Designed by Sir Alexander Rendel. Photograph by Fred Bremner, 1889 © Harappa.com.

bridge *is* "designed on lines of true economy,with the utmost simplicity and the lowest number of parts." Look at the photograph and see if you believe that. Another critic makes the same argument, though referring to London's Hungerford Bridge, another notorious design. The bridge is said to disprove the assumption "that if a structure was really scientifically designed it must be beautiful." Hungerford Bridge shows that such a structure "might equally well be ugly."[76] And what is so *scientific* about it? "The right factor of safety." As if there were only one way to ensure that! As if Science dismally compelled rational engineers to make the ugly form that strict calculations of safety dictate!

Other critics draw the conclusion I favor. What's wrong with Lansdowne Bridge is its insipid, even crude engineering. The words of one engineer-critic of this persuasion say it all:

> Contemplating the monstrosity of the general design, one would expect that in point of economy and detail of construction, a fair degree of excellence had been attained. But neither is this the case. There are many ways of reducing the unsupported lengths of the great uprights and raking struts, and consequently of reducing materials; but as these would involve some calculations of stresses beyond those of the most elementary kind, they were probably not deemed worth the trouble. . . . A derrick, the half of an English roof truss, a Whipple girder, the other half of the roof truss, and another derrick are excellent things in themselves, but to string them together up on a line, and thereby make a bridge, is not engineering, nor is it architecture.[77]

I think this criticism applies (mutatis mutandis) to all of the aesthetically notorious bridges. Their aesthetic failure is connected to everything that makes

them unimpressive, even bad engineering. The engineer-author of the study of aesthetically notorious bridges draws the opposite conclusion. He makes a sharp distinction between aesthetic motivation and technical expertise. He says that the designers of these bridges were evidently aesthetically unmotivated, but there's nothing *technically* wrong with their work, and no direct relationship between technical expertise and aesthetic awareness or concern. I don't know why he overlooks his own evidence of bad engineering in the bridges, or the fact that professional bridge designers take the lead in criticizing these works. Possibly it's because he thinks that, ugly though they are, the bridges are "structurally sound" and "functionally adequate." "As utilitarian structures, they all have served their principal purpose by safely carrying vehicular and pedestrian traffic."[78] In other words, tinned meat and powered milk! These bridges could have done what they are designed for and not been notorious eyesores. So how can they be really good, technically good, engineering, when much better bridges were technically within reach?

To return to Ammann's Bayonne Bridge I'm afraid that as built, the bridge suffers from visual enigma. Longer and thinner than Hell Gate, it is even more horizontal, a visual quality amplified by the long, straight approaches. At a crucial point, symmetrical at each end, where the upper chord of the arch stops, the bridge meets the approaches, and the truss transfers its load to the foundations, the form is visually tangled, busy, and confusingly articulated by the pointless boxy frame that was supposed to hold stone cladding (figure 4.9).

Ammann's piers were to have been lower than those at Hell Gate, intended to reach only the height of the road deck rail, but they would have been thick and rusticated. Visual mass at precisely that point would acknowledge and respond to the vectors of visual force that meet there. A frame of massive shapes in strikingly contrasting material would also enhance the curve of the bright metal arch. Were it made just that much more for the eyes as for the traffic, a poet might sing of Ammann's bridge as Hart Crane does of Brooklyn's:

> Accolade thou dost bestow
> Of anonymity time cannot raise:
> Vibrant reprieve and pardon thou dost show
> . . . . . .
> And of curveship lend a myth to God.[79]

## Aesthetics and Technical Design

My argument in this chapter has been that good technical design (good engineering, the best work) is at once aesthetic and structural/mechanical, because the

look and feel of a structure or device (perceptual interface) is as much a part of the design problem as its structure or mechanism (mechanical interface). That is not quite to say that successful technology has to be good-looking. There are many technically well-designed systems that you can't see, let alone take in and appreciate. One reason may be size. The Erie Canal (1825) ran 363 miles, linking the Great Lakes to the Atlantic. It was an important technology for developing the continental interior. Technically it worked well, though how it "looks," any aesthetic consideration, seems to have nothing to do with its accomplishment as a technology.

Let's consider the example more closely. The Erie Canal was an economically successful second-order machine, but the terms of its success favored the economic-political more than the technical-aesthetic. It was a successful technology by some measure, though it was not a notable accomplishment as technology or as engineering. It was important that it got built at all, important for what it did for the development of the interior. But as engineering, as a work of artifice and design, it has no outstanding merit. It's a big ditch. Let me suggest a different example, a notable piece of engineering by any standard, which it is impossible to take in as a visual whole—New York's Holland Tunnel (1927). This was the world's first major tunnel for automobile traffic. Cars and their exhaust raised to a new order of difficulty what had always been a major technical problem in mines and tunnels—ventilation. Designer Clifford Holland devised a system capable of exchanging 4 million cubic feet of air each minute. The expected volume of tunnel traffic was about 40,000 vehicles each day. On opening day, 52,000 vehicles passed through, and the ventilation was fine. Today about 80,000 vehicles use the tunnel daily. The ventilation still works fine.[80]

Two things stand out for me in this example. First, highly successful technical design obviously need not entail aesthetically compelling presence. I touched on this in discussing technical coherence in chapter 2. Technical coherence, the paramount design quality, floats free of aesthetic presence when, for instance, the system is too large or too small to take in perceptually. There can be other reasons, too, like being buried under the Hudson River. Second, even when a technological system lacks aesthetic presence, the way that no one can stand back and take in the Holland Tunnel as a visual whole, the concern for aesthetic look and feel reasserts itself at every interface, wherever humans have to collaborate in its operation, through maintenance, inspection, and so on, not to mention the experience of drivers passing though. One reason the Holland Tunnel ventilation system works well nearly a century after it was built is that it was designed with maintenance in mind, designed to be accessible, to be moved through and manipulated by a human body in a way that is coherent with our most efficient cognitive preferences. Those often turn out to be aesthetic preferences, too.

So even here, far below the Hudson River, there are subtle synergies of aesthetic and mechanical design. We can't take in the whole system, but the parts that we can and do take in look and feel right. That was probably true of the Erie Canal, too; for instance, at the locks, where mechanisms are hand-operated and require maintenance. Stretches of the canal as it rolled across upstate New York would have had visual presence for those who lived around it, though I wonder if it would match the canals of the English Midlands, which an engineer describes as "the one work of engineering which so far from conflicting in any way with the beauties of the natural world positively enhanced them."[81]

I should mention that it's no argument against the inevitability of a perceptual interface that technological systems consist of black boxes. A black box is not literally *invisible,* only its workings are, and only in the sense of not usually requiring attention or *needing* to be seen, which still leaves them available for "disinterested" observation, especially if they are designed for visual presence. A black box can always be opened, though normally it isn't. When we do open it, we interact with its parts, and ultimately that means our hands, eyes, ears, the whole body get involved. It is at that point that technical problems may reveal themselves to be aesthetic problems too.

To summarize what I'm saying about the relationship between technology and aesthetics:

First, insofar as a technological system is perceptible, taken in, possessed of expressive presence, a technically successful design (good engineering) has to include an aesthetically successful treatment of visual or more generally perceptual forces. It is possible for an economically successful technological installation (say, a strip mine) to flaunt this condition, but only because it is as cheap and insipid in its technology (its engineering) as it is ugly to look at and oppressive to be near.

Second, it can happen that aesthetic thinking about how the technological object looks is a way to work through the technical problem of form. This doesn't always happen but innovation often results when it does. The bridges of Robert Maillart (figure 4.7) are the most convincing example I know of this.

Finally, any technical or technological problem *can* be enlarged to take in the aesthetics of a work's existence in the world. It is greed, not technical rationality, that makes a strip mine an aesthetically aversive landscape. If the technological problem of extracting metals or minerals were not arbitrarily limited by short-term economic efficiencies; if the operation could be considered from the perspective of the human impact on the earth and the long-term survival of our civilization, then the technological problem of mining would not fail to include the aesthetic problem of how the work looks. It is not because they are so *techno-*

*logically rational,* so *functional,* or *well engineered,* that these installations are ugly, but because their design is compelled by management to be as brutally efficient as the owners can get away with. If consideration were given to long-term ecological costs, the engineering of the mine would eventually have to harmonize with the aesthetic conditions of its presence in the world.

# 5. ART



First, the artists have to create with technology because technology is becoming inseparable from our lives. . . . Second, the artists should use technology because technology needs the artists. Technology needs to be revealed and looked at—much like we undress a woman.

Billy Klüver

Billy Klüver was an electronics engineer and early laser researcher at Bell Labs. He was also the friend, assistant, and sometime collaborator of such artists as Robert Rauschenberg, Andy Warhol, and Jasper Johns. He advised Jean Tanquely on his *Homage to New York* (1960), a self-destroying kinetic sculpture installed (for the duration) in the garden of New York's Museum of Modern Art. In the late 1960s, Klüver was a leading figure in an Art and Technology Movement in the United States, having founded (with Rauschenberg) the organization Experiments in Art and Technology (1967). The idea was to cultivate the relationship between artists and engineers by supporting artistic experiments with technology and recognizing innovation in engineering. Around the same time, the Los Angeles County Museum of Art launched an Art and Technology program (1967), and there was parallel activity elsewhere, including the Computer Technique Group under Masao Komura in Japan (1965), and the 1968 founding in Paris of the quarterly *Leonardo,* dedicated to convergent discourse on art, science, and technology, by kinetic sculptor Frank Malina.[1]

These movements appeared at a time of optimism about a new American age of technology. Enthusiasm for technology waned with the 1970s even in the United States, where the elite were disillusioned with technology epitomized by

the Vietnam War, ecological crisis, and the domination of the economy by multinational corporations. All of that was before computers became inexpensive, before the digitalization of audio and visual information, before the Internet. These innovations breathed new life into an art and technology movement whose ultra-high-tech constructions include virtual reality installations and interactive on-line works.

Using advanced electronic communications technology as a medium for art is one of five major ways in which the paths of art and technology cross:

- Technology as a subject represented in art—mainly the work of interwar European movements, including Futurism, Constructivism, and the Bauhaus.
- Technologies of reproduction, especially photography, recording, digitalization, and hi-speed printing.
- Technologies of storage, conservation, and restoration.
- Technology in art's materials. Art has its own technics, its tools and materials, which are now usually mass-produced commodities of technological design and artifice.
- Technology as an artistic medium—the artistic use of technological systems, from photography (including cinema) to computers, Internet, digital sound and video, in multimedia configurations.

The first three are specialist topics I have nothing to say about. I begin this chapter with some observations on the fourth and fifth topics, the technology in art's materials and the technological art of multimedia. Then I turn to the relationship between art and aesthetics, including the idea, vigorously challenged throughout the twentieth century, that art has to be any sort of aesthetic accomplishment.

## Art's Technics

Art can still be made with ancient tools and materials. Yet even the most rudimentary artistic implements (brushes, paints) are now consumer goods rather than artists' secrets, produced under industrial conditions penetrated by scientific technology. A good example is paint and the colors available to painters. There was a time when a painter was necessarily something of a chemist. It was not until the latter nineteenth century that painters wholly relied on industrial, science-based technology for this critical material of their art. Color is now a thoroughly technological matter, deeply integrated with countless other industries and manufactures.

A list of colorants presently manufactured industrially covers nine thousand pages in nine volumes of *Color Index International.* There are so many not because the list registers trade names, but because there are so many colors available, with prosaic names like CI vat red 13 no. 70320 and CI food yellow 4 no. 19140, indicating hue, use, and chemical composition. The manufacture of dyes was among the earliest science-applying industries and the beginning of chemical engineering. "Out of bright purples and lustrous reds, shocking pinks and brilliant yellows," writes chemist-historian Philip Ball, "emerged all that is good and bad in this most mercurial of modern technologies: cures for devastating diseases, cheap and lightweight materials, mustard gas and Zyklon B, enough explosives to fuel two world wars and more, liquid crystals, and ozone holes."[2]

Earlier, I suggested that the first important application of technical design was in Upper Paleolithic works of painting and carving (chapter 1). These early artisans inaugurated what would become a long-standing pattern, where art drives technical experimentation and discovery. The metallurgist-historian Cyril Stanley Smith makes a persuasively documented case that artistic applications and aesthetic motivations lead the way in every major innovation in the history of metals prior to modern industrialization. The earliest metal was made by Neolithic people of Anatolia (central Turkey) around 8000 B.C.E. They were not just the first people to use metal; they were also first to take up settled agriculture and domesticate animals, all several thousand years before the first cities. The metal they made was copper, annealed and work hardened, its use limited to ornaments. Metal tools and mass produced weapons come much later, after 5000 B.C.E. Technical knowledge advanced quickly. By the early Bronze Age (third millennium B.C.E.), this culture was producing technically sophisticated metal artifacts on an industrial scale, and had developed nearly every metallurgical phenomenon known until the latter nineteenth century.[3]

Smith shows how the interest driving the exploration of metal's technical potential was invariably artistic. The secret of steel is a nice example. The exact difference between iron and steel remained unclear into the nineteenth century. It was known (for instance by Aristotle) that hot iron somehow turns into steel with lots of hammering. But exactly what changes and how? Aristotle suggested that hammering purified the iron, driving out gross particles and leaving only the finest, a kind of sublimation at the anvil. It was not until the latter eighteenth century that Europeans identified the intrusion (by hammering) of a small quantity of carbon as crucial to the transformation of iron into steel. The discovery wasn't made by industrial metallurgists, who, like scientists, did not yet exist. It was made by artisans attempting to duplicate a gorgeous Damascene gun barrel. "The investigation of an essentially decorative phenomenon, and an oriental one at that, thus led directly to the most important single scientific discovery in metallurgical history."[4]

Smith thinks that "from the cave paintings on, almost all inorganic materials and treatments to modify their structure and properties appear first in decorative objects rather than in tools and weapons necessary for survival. Aesthetically motivated curiosity, or perhaps just play, seems to have been the most important stimulus to discovery." Ball draws a similar conclusion. "A love of color ushered in the Bronze Age." Referring to the so-called Leiden and Stockholm Papyri—Greco-Egyptian texts of late antiquity containing the world's oldest surviving technical writings—he says, "The efforts of the ancient protochemists to create new colors established some pivotal ideas in the development of chemical theories. . . . If the Leiden and Stockholm papyri carry a scientific message, it is this: we can *create*. We can alter the shape, form, and appearance of matter. And in doing so we can add to the beauty of the world."[5]

Art always has its technics. A more recent development is a technological art, whose multimedia works orchestrate multiple technological systems, and often take their own technology as a subject for artistic comment. From speech and writing to photography and digital multimedia, technologies of communication seem always to inspire their own arts. The invention of technical media to facilitate communication could be as old as speech itself, if the shift from manual to vocal syntax was a cultural solution to a technical problem in the use of language by early *sapiens* (chapter 1). It is estimated that we were all speaking one language about fifty thousand years ago, which is about the same time as the modern human diaspora out of Africa.[6] As the most readily transportable of our cognitive gear, speech went everywhere we did and the different languages followed.

If syntax was originally manual (I'm assuming it is no more than a live hypothesis), and syntax on the spoken channel a technical innovation by early modern humans, it would be the first and perhaps still greatest effort to think instrumentally about communication as amenable to artifactual facilitation. Media have been technical ever since. To use them you have to put relatively complicated things together, using skills that have to be cultivated—not just performed by isolated individuals (like weaver birds), but studied and applied in social practice (like a scribe). Today, media technics are drawn into the global technological current. Everyday communications are now technological in the sense I explained (chapter 4), which entails emphatic technical integration, dense layers of artifacts responding to, communicating with, anticipating the performance of, other artifacts.

Beginning in the nineteenth century with the high-speed press, and traversing the electronics age from one end of the twentieth century (radio) to the other (Internet), communications media have become technologically dense and technologically integrated, wired deep into a global digital grid.[7] All forms of information—visual, sound, text, numbers—are now intertranslatable, conveyed in a

standard format, and can be sent or received from nearly any place on earth. Digital technology is a distinctly *technological* technology, a technology of technical interfaces, technologizing the communication of machines with machines, which is now as productive as communication with people. That's why information has become the material base of advanced economies, and why the largest part of the labor force in developed countries is engaged in information-processing activity.[8]

Multimedia art tends to make technology's density conspicuously present. It makes a show of it, makes the very technicality of high-tech media highly perceptible. These works are as lavish with technology as Jackson Pollock was with paint. They pour it on. Consider one example, a multimedia installation entitled *Rio Videowall* (1989) by Dara Birnbaum. Here is the artist's technical description of the work:

> Twenty-five color monitors (27-inch diagonal each), arranged in a five by five grid (Delcon Videowall system). Programming software: C-Through. Two live closed-circuit cameras with special-effects generator and preset video luma-key; custom-made enlarged lightbox (8 by 12 feet), vertically mounted on a wall of a main entryway to the complex [Rio Entertainment and Shopping Complex, Atlanta, Georgia]; and satellite receiver.

As for what it's about, here's the artist's statement of intention:

> The project conjoins the three elementary approaches inherent to the structure of video as a medium: prerecorded imagery, broadcast TV, and interactivity. The artwork utilizes these three significant features simultaneously, constructing a continuously shifting, fluid montage.

How?

> Footage of the site . . . forms a tableau that is disrupted by a continuous feed stream of the news from CNN. . . . Two interactive cameras . . . register images of passers-by . . . [which] appear as a silhouette within the prerecorded landscape footage. . . . These moving silhouettes are filled with images directly from a satellite feed of the news of the moment. Thus the passer-by's physical presence . . . disrupts a historical "electronic memory" with an influx of temporal information.[9]

As in this example, multimedia works often require unprecedented global coordination (satellite feeds!) and technical infrastructure. The infrastructure is typically expensive, requiring broad agreement on standards, and more planning and resources than any media in the history of art or communication. If digital technology is our most technological technology, multimedia is the technological

art par excellence—art using high-tech materials, with the performance of machines and technicians as important as what the artist does; and an art that makes the technological density of our civilization conspicuously, provocatively, artfully present to perception.

*But is it really art?* Of course. What else would you call it? It is art because of its genealogy, its historical context, not because it manages to achieve an aesthetic ideal. Art has no essence, least of all an aesthetic one. The relationship between art and aesthetic accomplishment is more complicated than essences are, because art is a contingent history rather than a formal concept. I want to look at two challenges to the idea that art has an aesthetic vocation, that it should be beautiful or at least sublime. The first arises from the diversity of world art and an anthropologist's suspicion that no concept of aesthetic value fits all cases. A second challenge comes from what is now a modern tradition of anti-aesthetic works, primarily stemming from Duchamp and conceptual art.

## Art's Aesthetics

> You know exactly how I feel about photography. I would like to see it make people despise painting until something else will make photography unbearable.
>
> Marcel Duchamp, to Alfred Stieglitz (1927)

> The impulse of modern art is to destroy beauty.
>
> Barnett Newman (1948)

Some anthropologists defend a view of cultures as symbolic systems of infinite nuance, unfathomable to outsiders without rigorous ethnography, maybe not even then. Our own ideas of "aesthetic value" and "work of art" are homegrown examples of such particularity. To search an alien culture for their aesthetic values or their works of art is as absurd as looking for their charity or their pope. "The category of aesthetics," it is said, "is specific to the modernist era . . . the 'aesthetic' is a bourgeois and elitist concept in the most literal historical sense, hatched and matured in the rationalist Enlightenment." The peculiarity of "the aesthetic" turns out to be its disengagement of the arts "from the social, the practical, the moral, the cosmological," modernizing art by purifying artistic activity "from the technological, the everyday, the productive."[10] Most other cultures do nothing of the sort. Ergo, other cultures have no "aesthetic values" or "works of art."

The difficulty with this argument is its narrow conception of aesthetics. The idea of a "pure" aesthetic response sequestered from utility, politics, or religion is weird even in the Western tradition, as is the value of "pure form" indifferent to content. The usual Western ideal is the unity of form and content. "Art for art's

sake" *is* a modern idea, though not our brightest one, and cannot be equated with the aesthetic mentality of either the Enlightenment or the present. Far from being summed up in the formula of "disinterested perception," Modern aesthetic thinking is more heterogeneous and pluralistic than at any time in the past. What distinguishes Western art since the Renaissance anthropologically from arts of other lands are its unprecedented pluralism; the length to which artists pursued mimesis; an appetite for individual expression; and a curious experiment with formalism, as if art could be improved by segregation from everything that endows it with value for life.[11]

We can notice this about Western art only from a comparative perspective, and what's being compared are arts traditions in different cultures. If art and aesthetics had no non-Western significance, we could not appreciate how weird it was for a European elite to take seriously the idea that there is a "true art" whose value is simply its purity. It was weird (even for Moderns) to set aside what most people everywhere take for granted, which is that art is a powerful means to something else, that it gives savor to life, however that is understood. Not art for art's sake, but art for the sake of the good life is the spontaneous aesthetic credo of *Homo sapiens*.

Ontologically, works of art are more like weeds than parking tickets.[12] Weeds are not merely conventional entities, like games, paper currency, or parking tickets. Yet there are no weeds in the primordial forest. Weeds exist because people plant crops. Arts, like weeds, grow everywhere, yet only on ground broken out by cultivation. Anthropologist Jacques Maquet argues that there are aesthetic qualities and accomplishments in any culture, and they can be appreciated by anyone who tries. "The components of aesthetic quality—clarity, simplicity, and integration of composition; expressive power; and discontinuity with the everyday environment—are not culture-specific, and consequently, aesthetic excellence may be intuitively perceived and discursively analyzed cross-culturally."[13]

The languages of central and west Africa distinguish *good* and *beautiful,* as do the classical languages of India, China, and Japan. There seems to be no culture that doesn't have something we can recognize as making and appreciating beautiful work. People everywhere single out particular works for aesthetic design, works *made* to appeal to perception. They can be anything: the paraphernalia of ritual, scarred or painted faces, weapons, pottery, song, dance. Different as they are, objects selected for aesthetic investment reveal a common profile. They are works of expertise and virtuosity; prized for nonutilitarian pleasure; recognized in terms of style; criticized by aficionados; bracketed from everyday usage; and usually involving representation and imaginative or symbolic interpretation.[14]

*The arts* is a collective name for the artifice of artifacts made to look or sound as they do. These works materialize the aesthetic qualities different world tradi-

tions have discovered and esteem. Works become artful as they take their perception into account, becoming *designed for perception,* made to *work* in being seen or heard. Such works are rooted in the capacity for second-order perception, the perception of perception (chapter 1). But art, or aesthetic design, is more than perception. It is artifice, which requires hands, dexterity, tools, and techniques. A culture and practice of aesthetic design (an art) can grow up wherever artifice anticipates and dramatizes the perception of its artifacts. Add the uniquely human capacity for high-fidelity imitation learning, the sociogenetic accumulation of innovation, and the usual human variation in talent, and the emergence of style and connoisseurship seem unsurprising.

"If there is any commonality among all the arts in all the places that one finds them," says anthropologist Clifford Geertz, it is not due to "some universal sense of beauty," about which he is skeptical. He thinks what makes art universally appealing "lies in the fact that certain activities everywhere seem specifically designed to demonstrate that ideas are visible, audible . . . tactible, that they can be cast in forms where the sense, and through the senses the emotions, can reflectively address them."[15] These "ideas" are the cultural meanings or symbolic significances of art (for example, why Christians depict their Savior on a cross, or why the Sudan Nuba paint geometrical designs on their faces and call them cowrie shells). Geertz downplays the technical presuppositions of the symbolic practices he identifies with art. I see a difficulty in that. To make an idea appealingly visible, I have to make a compulsively visible artifact. That requires technical skill, and *that* is art in the primary sense of the word. Visual artistry extends to depiction or representation, which is not only a matter of symbols, but also the artful exploitation of perceptual cues, many being common to people everywhere.[16] Clearly artifice like that is not something anyone can do, and people everywhere seem to recognize specialization in a repertory of difficult media. The most praised works show exceptional technical skill by anyone's standard.

The art of such work, with its aesthetic presence, its perceptual expressiveness, its visuotechnical coherence, has practically nothing to do with the language games people play with it. It is the designed, artificial, artful convergence of these technical and aesthetic qualities that makes a thing suitable for heavy carrying in cultural symbols. A people's art can be a system of cultural symbols only if it is also a technical economy of appealing, aesthetically designed, perceptually expressive works. Cultural symbols may be arbitrary but aesthetic presence is not. The work matters. Art and technique matter. It matters how the work is put together. And it matters in a way that can be appreciated by anyone who wants to learn.

I am not defining art as an aesthetic accomplishment. I am not saying that art has to have sensuous appeal, let alone beauty, even though that is how most people

have felt about art for some thirty thousand years. Perhaps they were confused. In any event, twentieth-century artists established an ironic tradition of anti-aesthetic art. They accomplished that with a series of sometimes notorious works that mock the aesthetic interest of art.[17] The effort may be nihilistic, as I think it is, but there's no denying what's been done, that artists did it, or that it's art.

The abuse of beauty began in central Europe around 1915 with the Zürich Dada group. They were appalled by their patrons, bourgeois nationalist war-mongers who thought they were lofty and cultivated and expected beauty from the arts. Instead of a passing fad, Dada inaugurated a Modern tradition—what philosopher of art Arthur Danto calls the *intractable avant-garde.* They have given us works that no passage of time, no cultural or perceptual mutation, will allow to be seen as beautiful or aesthetically valuable. "It is essential to their aims," Danto observes, "that the disgusting remain disgusting, not that audiences learn to take pleasure in it, or find it somehow beautiful."[18]

Some may want to say that such works just aren't art at all. The impulse should be resisted. The invincibly ugly work of an intractable avant-garde includes some of the most conspicuously successful art of the last century. From Marcel Duchamp's *Fountain* (1917) to Andres Serrano's *Piss Christ* (1987), the art of the twentieth century harbored militantly anti-aesthetic artists. You have to call them artists because everybody does and they cannot all be wrong. *What else* would you call Duchamp? Charlatan? But that's argumentative and lots of people disagree, so we get nowhere. A scholar of things Duchampian in twentieth-century art asks, "Who would dare deny that Duchamp's urinal [*Fountain*] is art? Such is its status in any case or it wouldn't be on the record. What is also on the record is that cohorts of artists registered that Duchamp's joke had passed the test and went on to play variations on it, pushing the limit of art further and further, probing its boundaries, some jokingly, some in dead seriousness. . . . Unless one is ready to erase from art history the innumerable works that have been authorized by Duchamp's readymades, it is impossible to deny that, whether good or bad, they are art."[19]

Duchamp initiated a shift in the center of gravity of modern art, from a finished product (the work) to a process in which the audience is complicit. A convenient name for such work is *conceptual art.* It is an art of doing (or happening), not making; an art that mocks aesthetic workmanship to focus on an artist's (rather than an artifact's) performance. The residue, the provocation, the nominal work, is aesthetically indifferent if not ugly. The work can be anything (a urinal) or nothing at all (in John Cage's *4'33"* a piano is *not* played for the interval). It doesn't have to involve any technical skill, as Piero Manzoni's *Artist's Shit* (1960) convincingly demonstrates. The "piece" may be a happening or performance rather than an enduring artifact, as in Chris Burden's "Five Day Locker Piece"

(1971), in which the artist spent five days in a two-by-two-by-three–foot locker set up in a gallery. The "piece" doesn't even have to be *worked* or be *a work* at all. It can be a natural-born living thing, an animal. As it happens, there's a horse named A Real Work of Art. A part-owner is British artist Mark Wallinger, and he turned A Real Work of Art into a real work of art.[20] A Real Work of Art is the name of a horse, but "A Real Work of Art" is the name of a work of art, which is a horse named A Real Work of Art. Get it? It's *conceptual.*

How can anyone turn a horse into a work of art? Anyone can't. You have to be an artist. If you're an artist, though, all you've got to do is do it—plus get your gesture confirmed by agents of the artworld, the people of the museums and galleries, the trade magazines, art schools, and universities. The economy of recognition seems to be all there is to conceptual art, and it has inspired philosophers to think it may be all there is to art.[21]

Compared to more generous (less nihilistic) art no less emphatic about process and transience conceptual art seems petulant and resentful. A Navajo sandpainting may require four hundred artisan-hours of construction. When complete, the work is used for only a few minutes before it is swept up and ritually destroyed. Yet in its brief existence the work is wonderful, and its obliteration before the eyes strikes a deeper note of feeling than the farcical indifference of the readymade or the contrived spontaneity of the happening. Artist Sol Le Witt (who coined the expression "conceptual art") writes that "in conceptual art the idea or concept is the most important aspect of the work . . . all planning and decisions are made beforehand and the execution is a perfunctory affair. . . . What the work looks like isn't too important." As usual, Duchamp was already there. He called for art that "reduce[s] the aesthetic consideration to the choice of the mind, not to the ability or cleverness of the hand."[22] I wonder what he thinks an "aesthetic consideration" *is?* I say it's a consideration of *appearance,* and therefore depends on how a thing is *put together,* "cleverness of the hand." To refuse to put anything together, as Duchamp does with his readymades, is to nullify the aesthetic, not to transfer it to a conceptual order.

Conceptual art became possible after we became accustomed to distinguishing a few "fine arts" supposedly preoccupied with beauty (in German, the fine arts are *die schönen Künste,* the beautiful arts). Institutionalizing a canon of fine arts, carefully purified from innumerable less spiritually elevated *ars* and *techne,* became a hallmark of European modernity. The genealogy of fine art begins, however, with the egoism of two Renaissance painters, Leonardo and Michelangelo. They launched the idea that painting and (perhaps) sculpture were special arts, not mechanical, not merely useful, but liberal, intellectual, spiritual arts. By the end of the eighteenth century, the difference between the fine arts and merely utilitarian techniques or technologies seemed obvious. By the end of the next century,

this was the obvious difference between the rationality of engineering and the subjectivity of art. Today it is almost mischievous to mention painting and sculpture with carpentry and cooking as so many *arts.* Painting and sculpture are *fine* arts, which is now the primary connotation of the word *art.*

Modern philosophy rationalized the purification of a few fine arts from the confused morass of *ars* and *techne* with its concepts of beauty. Kant spoke of purposiveness without purpose. Hegel saw the emergence and perfection of the Idea of Beauty as a necessary moment in the historical movement to Absolute Knowledge. In retrospect, however, this dichotomy between fine arts creating beauty and utilitarian technologies compelled to mere efficiency seems not a good idea. For one thing, it isolates art and beauty. It assigns Beauty to Fine Art like Truth to Science or Duty to Morality. All the *other* arts have no stake in beauty, and fine art has no stake in anything else. Most of the arts are dismissed as philistine economism, and the fine arts are burdened with an increasingly unrealistic expectation of spiritual beauty.

The same scholar who extracted our acknowledgment of Duchamp as an important modern artist is reluctant to call anything the man did "great art." He carefully calls the work *significant*—"significant art, highly significant of the plight of our culture."[23] Precisely. Besides being an artist, significant if not great, Duchamp was a nihilist. In following him artists reveal their own nihilism—how sick they are of art, how hopeless they feel. Why do I say *nihilism?*[24] The word seems appropriate for the thought that nothing is worthwhile, nothing significant, nothing transcendent; that everything is equal, nothing better or worse than anything. It is unlikely that a person could survive uncompromising nihilism. Even Duchamp loved chess. He probably thought it was a much more interesting, intelligent game than tic-tac-toe, and he's right, however inconsistent that may be with the nihilism of his art.

The nihilism of the readymade is at once aesthetic and technical. It doesn't matter how it's put together or how it looks. Duchamp says, "A point which I very much wanted to establish is that the choice of these 'readymades' was never dictated by aesthetic delectation. This choice was based on a reaction of visual indifference with at the same time a total absence of good or bad taste . . . in fact a complete anesthesia." Anything, nothing, an indifferent piece of hardware, is as good as tradition's best works. "I just wanted to react against what others were doing, Matisse and all the rest, all that work of the hand . . . all that retinal painting." As it turns out, Duchamp wasn't much talented at retinal painting. It took a kind of genius to turn this liability into a new art. Duchamp is the first important artist who is not an important painter, sculptor, or master of any technical medium. He is the first important artist who never made an important work of art.

For this art, if it is still art, technical skill is to be "felt as impossible by the sensitive artist. . . . Gone is the skill, the talent, what remains is the genius, the wit."[25] Yet we value genius and wit by their work. Take away appealing work and wit or genius may be hard to distinguish from chicanery or madness. If you judge the wit by the work, Duchamp is witless as a suicide. Had he lived in ancient times he probably would be regarded like Diogenes the Cynic, as a witty performer and philosopher rather than a *technites,* an artist. His antics on the high ledge of Modernism have a morbid fascination for the nihilist in us all. But what misfortune that his fulsome resentment became a defining moment in modern art! Duchamp's readymades reverse all the technical values of art—skill, workmanship, expressiveness, aesthetic presence—and invite us to mock them, *which we did!* Given the chance to react with undisguised malice against a tradition that imposed supreme difficulties on accomplishment, generations of modern artists grabbed it. Given the opportunity to take revenge on the past, they outdid each other in highly public manifestations of *our* nihilism, our hopeless indifference, our sickness of art.

By abandoning the values of technical skill and aesthetic presence art gives up what makes it appealing and worth cultivating, and tends to slip into a condition of terminal *who cares?* It's amazing that people persuaded themselves not to expect beauty in the arts. On a long view, the practice of artistic, artful, aesthetic design is somewhat more than thirty thousand years old. In all this time the bond between art and aesthetic accomplishment is everywhere taken for granted, with the exception of a single sanguineous century in Europe and America.

Critic Donald Kuspit thinks most art today would be better called post-art, which he explains as "a crowd phenomenon with the honorific identity of art, but without its transcendental ambition and aesthetic substance."[26] Art has been pronounced dead before, beginning with Hegel in the 1820s.[27] Of course there were many important developments in Modern art after 1829, when Hegel last lectured on the subject. Isn't it the same now? Won't art keep surprising us? Perhaps. You've got to wonder, though, how long artists can evade the consequences of their nihilism. Art has not sublimated into science as Hegel predicted. Instead it has nihilistically abandoned artistry, replacing enduring works with witticisms that look more like self-promoting antics or mass media entertainment than art. If that's the future, then art does not have a future. But maybe artists can go only so far in contempt and indifference to aesthetic appeal and the technique that makes it possible. Maybe the invincibly ugly work of an intractable avant-garde will attract increasingly few by its resentful gestures and the demoralizing belatedness that makes them appealing, and will disappear like the Bogomils and Eonists, forgotten heretics of troubled times.

## No, Not Another Definition of Art!

> Only that which has no history can be defined.
>
> Friedrich Nietzsche

The last thing we need is another definition of art. The whole idea of a defining essence or nature—for art or anything else—is a relic of an era before Darwin. An essence or nature is supposed to be an eternally valid necessary and sufficient condition for being a kind of thing. But there are no such conditions and no such kinds of thing, no natures or essences as Western metaphysics understands those ideas. Practically everything the sciences surmise about the universe, the planet, and the evolution of life tells against the Greek idea of nature as eternal, changeless, closed, or finished. Of course, the anti-essentialism of modern cosmology, quantum mechanics, and evolutionary biology doesn't logically imply that art, too, lacks an essence. But it softens you up for it. How could something that doesn't have an essence (us), living in an uncertain, indeterminate, deeply contingent cosmos, manage to make something (art) that has a good old-fashioned essence? How could something contingent and changeable create something eternal and necessary?

Essences induce giddy swings between extremes. First we believe in essences and are fanatics for their truth. Then we recover from essences and denounce them as empty names, mere words. No essence of Art, ergo art is *anything, ergo nothing at all.* Once we were realists about art—it has an essence. Now we are nihilistic nominalists—it's just a name, a convention, an institution.[28] Nothing about the work itself has value. It's all in the language game, which is arbitrary, a game of social power.

This is not a debate I want to join. You can't win an argument against nihilism, since the nihilist has nothing to lose, and realism versus nominalism about essences has been a standoff since the Middle Ages. Two intellectual breakthroughs from the nineteenth century suggest an alternative point of view. One is scientific historiography, by which I mean our modern academic approach to historical scholarship. The discipline instils the difficult lesson that there are no origins (difficult because against the grain of mythology). Nothing historical simply begins, unconditioned by a historical past. For anything history can demonstrate to have occurred, there is more to its conditions than history can know. We hear the same from evolutionary biology. Darwin urged naturalists to "regard every production of nature as one which has had a history." A species is a branching point in a genealogy that, like the historical past, is virtually endless. Evolutionary research is genealogical, reconstructing the vicissitudes of form down lines of descent. Such research is inevitably fragmentary, incomplete, lacking simple origins and final

ends. For Darwin, ultimate origins were the very type of the pointless question. He writes to himself in a notebook, "It is useless to speculate not only about the beginning of life but even about great division. Our question is not about how there came to be fishes and quadrupeds but how there came to be many genera of fish &c &c at present day."[29]

There is no "essence of art" because essences do not exist. However, before we let the realist/nominalist pendulum fall, why not apply the genealogical perspective?[30] Like any historical entity, there's no saying what art must be, only what it's been. Looking into its conditions, we find a genealogy that never reaches a simple origin but, on the contrary, becomes more diffuse and difficult to discern the further back we go, until all trace is finally lost. The history of art has become a controversial field of scholarship. There's no agreement on exactly what does or doesn't belong to art's history or why.[31] The uncertainty shouldn't make us rush to proclaim with the nominalists that truth is power. We see comparable uncertainty in evolutionary natural history, which still manages to be a respectable scientific field. The evolution of horses, the reconstruction of *T. rex,* the genealogy of modern humans—all of these have seen controversy and sometimes dramatic reversals of opinion. Uncertainty can be a characteristic of a mature science, as a mature philosophy of knowledge will allow, having learned from the experimental, historical, and biological sciences to not pursue antique ideals of certainty, necessity, the eternal, or changeless, and to forget about essences.

A biological genus is not a thing in itself with an identity all its own. It has no timeless essence, no eternal form or idea that preexists the evolution of its species. A genus is an evolving, four-dimensional, genealogical entity, an irreversible, ateleological sequence of descent with modification. It is only retrospectively that we discover *Homo* as a genus in primate evolution. There is nothing "fully present" in the first species of *Homo* that determined the course of human evolution. So too for the first arts. We can no more explain the first arts than we can explain the first species of the *Homo* genus. This species (*H. ergaster?*) would have appeared as a mutation, a variation on an earlier, established species, presumably one of the southern australopithecines. The first mutant *Homo* species would have been utterly unpredictable, a chance variation that happened to survive. Descendant forms, modified under natural selection, were no less fortuitous, right down to *sapiens.*

Why not the same picture for the first art? It would have begun with a few early species, which would be whatever artifacts humans on the cusp of cultural modernity designed for perceptual expressiveness or aesthetic presence. With music and dance, that probably included painting, scarring, or otherwise decorating the body. Carving ivory and painting caves comes much later.[32] Stone tool forms, especially oversized and notably elegant ones unlikely to have been made

for use, may be an independent origin of aesthetic making, perhaps as old or older than body-marking, although that would be difficult to prove. All human beings ever since are descendants of these first artisans, and so is all their art. To be a work of art is to take place in this history, to be conditioned by it, to emerge and grow in its contexts and traditions.

There is no one History of Art in the sense of a story that starts at this zero point, and weaves all the works of the world into a progressive sequence to the most advanced form. That's not the pattern historical scholarship and evolutionary biology teach us to expect. Evolutionists don't expect evolving species to line up in rank order. On the contrary, theory predicts species diverging from each other like branches on a bush, an expectation usually confirmed in the fossils. I think this is a helpful metaphor for thinking about the arts. On the one hand, the drift in arts is toward profusion and local differentiation, not progress towards a single ideal. On the other hand, a continuous genealogy links the paintings at Chauvet Cave to Jackson Pollock. A parallel genealogy links the elegant stone, bone, and horn tools of the Upper Paleolithic to the technology of the moon landing and the Internet.

Artifacts participate in art to the extent that they are designed to be perceived. Art makes things that *work* by getting people to look, to linger, to remember. They may aim to please and delight, to overwhelm and intimidate, to puzzle, even to disgust. The point is that they look (or sound) as they do so that others will pay perceptual attention, making them difficult to overlook or forget. That does not mean "beautiful." It means designed for expressive, aesthetic presence. Even *Fountain* has such presence, the hardware becoming scandalously visible and obviously very memorable when recontextualized from public toilet to juried exhibition.[33] *Fountain* participates in art and belongs to its genealogy through Duchamp's artistic training, through the convention of submission to an exhibition, through a famous photograph by Alfred Stieglitz, and not least through its highly memorable if entirely imaginary presence, attained not in the usual way (by how it's put together) but "conceptually," by scandalous recontextualization.

Conceptual art, performance art, and the invincibly ugly art of an intractable avant-garde all belong to art's history. The question is whether they belong to art's future. One can only hope not, for nothing comes from nothing, and for this art, art is nothing.

It may seem unusual that I talk about art without considering what to many are its most obvious qualities—representation, or being about something, and self-expression. It is of course true that many works of art have these qualities. It is also true that many do not. Yet the topics of representation and expression have

received so much emphasis in the philosophy of art that I'm making the experiment of reasserting as forcefully as I can the neglected topics of artifice and design. Obviously I'm not denying that works of art may be representational or self-expressive. But that's like saying they can be given as gifts—true but unrevealing. Neither of these qualities are what makes art art. What makes art art is genealogy, and the lines of descent are the intergenerational transmission of technical, artisanal, artifactual craft, style, and technique. Even Duchamp and so, indirectly, *Fountain* has such a lineage, and it's that genealogical context, not an essence or an institution, that makes it a work of art.

Part of my experiment is to drop the presumption that what's "expressive" about art must have something to do with the artist's subjective feelings or identity. As I explained in chapter 3, aesthetic expressiveness is a quality original to a work. It begins to exists with a work, not a feeling or intention. Aesthetic expressiveness is primarily a matter of technique, technical invention, pedagogy, and practice. To make an expressive work of art takes art, not feelings, nor is aesthetic expressiveness limited to subjective feelings. Theoretically, visual art could express any visual quality, which it does by imitating cues that viewers pick up despite an almost arbitrary difference of material—like imitating the look of plowed earth in gold relief, to mention an example from Homer I'll return to. The practice of art begins with the discovery that works can be *designed* to be memorable, delightful, even sublime perceptions. The aesthetic, artifactual, nonsubjective presence I've tried to elucidate in terms of expressiveness is an effect and can be imitated, that is, reproduced artificially by an artful synergy of second-order perception and manual technique. Accomplishing this presence is the work of the first works of art, and remained the work (the point and value) of art for most of human history.

With the exception, perhaps, of Duchamp, wit just isn't enough for art. At some point, you have to make something, the hands must collaborate, which implicates a historical economy of technical skill and doesn't emerge fully formed as an innate, isolated gift. The expressiveness, the presence, the compulsive, memorable perceptibility of works that have those qualities does not intentionally preexist as a form or idea in the artist's mind. It belongs to the work, begins to exist with the work. Thanks to the artist, of course, though the intentional contribution of artists' subjectivity should not be exaggerated, nor their skill, craft, workmanship, training, and artistry neglected in the theory of art. That's why I side with Michelangelo against Kant, with the actual work over the transcendental imagination. A "work of the imagination" is a work of art only if it gets out of the imagination to lead an artifactual existence in a technically mediated public sphere.

## The Work of the World

> Every artificer aims to produce a work that is beautiful, useful, and enduring, and only when it possesses these three qualities is the work highly valued and acceptable. Knowledge renders the work beautiful; the will renders it useful; perseverance renders it lasting.
>
> Bonaventure, *Retracing the Arts to Theology*

Works of art and technology don't require profound innovation merely to be good or even beautiful. The largest part of scientific work, according to the influential view of T. S. Kuhn, is "normal research," laboratory puzzle-solving. It may produce surprising results, but rarely sparks a revolution. The same goes for art and technology. A bridge, ship, or aircraft can be good work (good design, good engineering, good looking), even though it follows known principles and sets no record. A painting, drawing, or ceramic can be exquisite without being "creative," when it is simply (simply!) wonderfully well done. "Novelty can be exciting and delightful in art as in other affairs," writes philosopher of design David Pye. "But art exists in its own right, independently of novelty." Art "has nothing to do with the fact of new invention, it resides in the quality of what has been invented."[34]

Quality (art, artistry, artfulness) in a work, whatever it may be, has two dimensions—design qualities, and the qualities of artifice or workmanship. Either may be good or bad, mechanically, structurally, or aesthetically. The best work, from bridges and ships to paintings and symphonies, is good design well realized by good workmanship. Pye defines workmanship (what I'm calling artifice) as everything about the appearance of a work that cannot be communicated by speech or specified by drawing. The quality of workmanship depends entirely on the skill, care, and judgment of those who translate plans and instructions into finished work. "No drawing, however fully and minutely dimensioned, can ever be more than a sketch as regards the appearance of the thing drawn. The eye and mind discriminate things which can never be specified or dimensioned: the qualities and colors of surfaces, the minute variations of profiles, and still other nuances of shape too tenuous and subtle to describe in practice." Artifice takes over where design stops, "and design begins to fail to control the appearance of the environment at just those ranges at which the environment most impinges on us." By generating diversity on many levels, artful artifice extends the aesthetic depth of artifacts well beyond the control of design, "down to the smallest scale of formal elements which the eye can distinguish at the shortest range."[35]

Artifice, workmanship, may be good or bad but not new; innovation, whether in art or technology, belongs to design. Yet design is decidedly a junior partner in this ancient alliance with artifice. Artifice is as old as artifacts, as old as the first stone tools and the earliest *Homo,* much older than design, which emerges as the

principle of a sustained accomplishment first in the Upper Paleolithic. Not only does design supervene on artifice, being powerless to bring itself into existence. There is no design apart from undesignable, unspecifiable, unmechanizable artifice. No matter how dense or ingenious the technology, hands and their work—artifice—will always be indispensable. It is artifice, workmanship, that discovers the designable potential of materials and processes. Designers don't just get ideas. They get them from experience with what artifice has accomplished. It's Michelangelo and Kant again. The design (purposiveness) that matters to art is the quality of an actually executed work, not an imaginary mental construction. Designs do not exist "as such," as finished forms in an ideal realm of mind, apart from the work whose design they are. An idea in Michelangelo's mind, or an image in his imagination, is not a design or a work with a design. Engineering drawings as detailed as you please are not a design. They are plans and instructions for realizing one.

Good work in art and technology are examples of accomplished knowledge, which I explained (chapter 1) in terms of superlative artifactual performance. What comes first, in art as in technology, is the artifact along with its performance relative to a history of practice. A "conceptual" art that disregards the work, aesthetically and technically, remains "art" in a nominal sense (unless "post-art" catches on), even though it nullifies the accomplishments from which it emerges in the genealogy of art. My criticism of conceptual art has nothing to do with some idea of art's essence or an ideal of beauty. It concerns the technical and aesthetic values of artifice and design. These artists repudiate the value of anything that lasts, deconstructing the assumption that art should be work worth caring for. The outcome is nihilistic rather than aesthetic, meaning that it appeals to artists' (and audiences') nihilism rather than their capacity to invent and enjoy aesthetically expressive works.

Who cares about a few nihilistic artists? Who except themselves and their apologists takes them seriously? Yet their hopelessness, their lack of a public, like their indifference to artifice and design, is our problem too. Let me explain why. Art historian E. H. Gombrich writes that "it is artifice which is called upon in human culture to resist change and to perpetuate the present. Where things decay the craftsman can create the substitute that remains." Hannah Arendt had a similar idea, as did Martin Heidegger.[36] With works that endure, art discloses a world to each generation, a world of durable, finished things that are as they are, an "objective" (albeit artifactual) world distinguished from the subjective, private, irrational ebb and flow of animal life. Works, especially their presence, make a world visible and tangible, an "objective" world of finished forms, a cultural world that transforms the laborious existence of animals into a human life through participation in practices under the shelter of works that last.

Perhaps Arendt is right that it takes such works, including poetry and architecture, to relieve political life (and its sacrifices) of futility and nihilism. Nature is all process. Life and death are continuous and ultimately indistinguishable. It is consciousness and especially speech that punctuates process, defining moments of life (births, deaths, triumphs, tragedies) that would vanish from consciousness as they do from the present without a monument, even if only a name. These works work against nihilism, against demoralization, against loss of interest in what the world has to offer, which is why a cunning nihilist like Duchamp chose his target well, subverting the work that makes the world.

Conceptual art and technological trash make a weirdly complementary pair, symmetrical in their nihilism. Conceptual art is art even though its "works" are of indifferent artifice and design, while our high-tech economy obliges us to trash works that are exceptionally well made, even intact and operational. The art gives us nothing worth keeping, and we have to trash what ought to be worth keeping, considering how well made it is. This nihilistic indifference to indifferent artifice—no obstacle to art, and no more likely to be trashed—subverts a custodial relationship with artifacts that is as old as the social relations we have with each other.

It is a paradox of technological trash that things may be so well made they can't be repaired when they fail and must be trashed with all their parts (a video monitor, for example, and automobiles bristle with unrepairable black boxes). Before industrial automation, when well-made things were relatively rare, they were almost always worth repair. Repair is a kind of care and with time it generates works whose care is inherited and passed on. Repair is a caring reply to skill's art, as well as an expression of the economic balance between knowledge and works. Works didn't approach the limit of users' knowledge until they were deteriorating, when they were finally trashed. There's greater incommensurability today between works and users' knowledge. A work can quickly pass the limit of knowledge and become trash, despite remaining very well made and having lots of potentially (but only potentially) reusable parts.

We have never made so many works we don't care for or trashed so many tools. It's an injustice against artifacts to make them not worth caring for, and a calumny against art and knowledge. Human beings have cared for artifacts as long as we have cared for each other, which is to say from the beginning. The usual reason works elicit transgenerational care is because they are well made. They have (and hold) value, not by convention but because of their quality. From bridges, buildings, even whole cities, to swords, family silver, or a collection of paintings, the reason these things are worth care is the rare quality of their artifice. Even when they don't last, when they are ruined, they may still be beautiful, as sculptor Auguste Rodin attests. "More beautiful than a beautiful thing is the

ruin of a beautiful thing."[37] Because it is still beautiful. Because even ruination cannot overcome its presence. And because it is a more complex beauty, tinged with expressive pastness, disclosing the past as ruined and the present as the future's past.

How do we reproduce a world that works if well-made things are not worth repair? Formerly, being well made and working well were typically coextensive. What was well made worked well and was worth repair. However, it is clear that being well made and working well are no longer the same value. Technological obsolescence can make very well-made things unworkable. It is also clear that working well is more important than being well made, because we have no reluctance (often no choice) in trashing well-made works, though if something works well (as opposed to being merely well made), it is less likely to be trashed. Being well made, being durable, is not enough. It is even part of the problem, the new form of the problem of trash—its durability; for instance, the durable half-life of nuclear fuels, committing us (with baffling confidence) to millennia of expensive care. The durability of the world has become divorced from the durability of works. We can no longer make a durable world by making durable works, because our durable works become enduring trash and threaten the ecological compromises on which our form of life depends.

Things that work well (all things considered) resist obsolescence better than things that are merely well made. The art of design has an edge over artifice, because only an accomplishment of design can make a thing that reliably works well and isn't just well made. Of course, I mean design in the philosophical sense of this book. That's not what is often called design today. *That* design is preoccupied with stimulating desire and attracting consumers. This aestheticization of the commodity is a twentieth-century phenomenon, a product of the expansion of the consumer market and the democratization of taste.[38] Such "design" is often errant, playful, obsessed with look and feel. Less important is the work's being well made. Even less, its working well. Least of all its real cost.

We have to waste less, a lot less. The alternative is the chaotic vortex of extinction. Perhaps we could evolve an art of design or engineering that puts durable working ahead of merely being well made. Design with those values would work with the long-term ecological cost of artifice. It would design for reuse at every level. Works would be *made* for recycling, which would be part of the engineering problem of making them work together in the first place. I'll come back to this point in my conclusion. Whatever the work, whatever it is made of, the more of it that can be *folded back* into renewed *techne* the better. There is nothing offensive about a well-made work that no longer works where installed, provided it can be recycled into works elsewhere. To maintain this reversibility is, as Bruno Latour says, "the current form that moral concern takes in its encounter with

technology."[39] Of course, such an art will not appear merely because civilization requires it. Neither can markets be guaranteed to discover it before older ways take us over the brink of extinction.

## The Idea of Art

> The idea of art as a conscious idea—the greatest intellectual achievement in the history of humanity.
>
> John Dewey

Art is not human nature. If we take a long view, if we appreciate humanity as an evolved entity, there's no escaping the conclusion that for most of *Homo sapiens'* existence—our first hundred thousand or more years—art, design, technical invention, ingenuity, even knowledge were not conspicuous qualities of human life. The evidence pretty clearly shows that art is not an evolutionary adaptation, not something humans have always instinctively done. Instead, the potential for art and design, like the potential for knowledge (perhaps even speech) had to be discovered and cultivated, making art more like a good idea than an instinctive behavior.

Getting the idea of art means beginning to practice design in artifice, design at once technical and aesthetic, designing (technically) with tools and materials for perceptually expressive (aesthetic) effects. Painting and carving, the oldest plastic arts of design, synthesize second-order visual cognition and manual technique. We have always enjoyed good vision, but hadn't perceived our perceptions, hadn't been shown them and made to think about them, until the first visual art did precisely that, translating vision from a neurological to a graphic medium by the intermediary instrumentality of hands and their tools. That is the beginning of graphic design, which is the beginning, if only that, of visual art.

The earliest aesthetic judgment in the Western record is in the *Iliad* (eighth century B.C.E.). The poet praises the shield of the hero Achilles. Part of the design is an image in gold relief of a newly plowed field. "The earth looked dark behind the plough, and like to ground that had been ploughed, although it was made of gold. That was a wonder to behold!"[40] "Wonder" (*thauma*) names the appealing reaction to the visible, mediated, isomorphic reconstruction of perception in material you would never associate with it. The inverted alchemy of art makes dirt from gold. More precisely, it makes *the look of dirt* from skillfully worked gold, *the look of* women from carved ivory, *the look of* bright eyes from sooty oil. The alchemy is delightful because we are not duped, as patrons of alchemy were, or like the birds who tried to eat Zeuxis' painted grapes. In art there is no illusion. We see drawings and paintings as exactly what they are—artifacts designed to

attract and hold visual attention, which they do by a media-metaphoric translation of perception, constructing a visual isomorphism of conspicuous artifice in a ponderous medium far removed from the neurology of vision.[41]

We had to discover the possibility of cultivated coordination between visual and manual agency. Like other historically discovered potentials, including agriculture, writing, calendrics, and cities, art is an idea people get, a goal they invent or acquire, a practice they take up, a cultivar they cultivate. You may wonder whether there can be an idea of art when, as I argued, art is a history and not an essence. It is an originating idea, a highly original innovation, like the first species of a biological genus, and it is as changeable as any form in evolution. The whole history of art (from about thirty thousand years ago) is also a late, highly advanced stage in our evolved commitment to an ecology of cumulative artifice (chapter 1). By now, art is a mode of material and structural transformation to which we are committed not just as a civilization but as a form of terrestrial life.

We become committed to art because of what it does for us, an accomplishment taken for granted only because we have built so much on it that we can scarcely imagine a time when we didn't have it or its works. Rudolf Arnheim is probably right to think that the arts are "the most powerful means of strengthening the perceptual component without which productive thinking is impossible in any field of endeavor."[42] Kimon Nicolaïdes, an artist and teacher, says that "learning to draw is really a matter of learning to see—to see correctly—and that means a good deal more than merely looking with the eye."[43] Leonardo probably understood things we still don't about hydrodynamics because of what he saw through his drawing. In his pencil he found what drove the later refinement of the telescope and microscope—an instrument to make vision more perceptive. A scholar writes of Leonardo's "profound awareness of the act of drawing as an extension into the world, a process of seeing, knowing, and possessing, of that mutuality of hand and eye—and body." "Through graphic gesture he could make visible those forces of nature that seemed to lie beyond the threshold of normal perception. Most impressively, he could see and record complex movements of water because he could impose upon the natural phenomena his own graphic formulae."[44]

Vision may be less a condition of art than art a condition of vision, especially objective, disciplined, scientific vision. Of course earlier people without visual art had vision, as do chimpanzees, birds, fish, and so on. But these other eyes don't see their vision, and certainly don't have it called to their attention by the appealing translations art presents. Once we are conscious of (or learn to perceive) our own perceptions (second-order perception), and acquire the knack of translating perception into a medium, the sight of other species can't look the same. The art of depiction reacts on perception, reconstructing vision.[45] Vision becomes artistic before it becomes objective. We see more expressively because that is how art

presents perception to us, and we have come to invest perceptual expressiveness in practically anything we make. We have, as I said earlier, no idea how to make something that's purely functional, a rational instrument blindly indifferent to appearance.

Design seems to have made little contribution to technical culture until the Upper Paleolithic. Consider, for example, the Acheulian teardrop stone tool I've mentioned several times (figure 2.1). This form was invented about 1.5 million years ago, then doggedly reiterated for more than a million years. I mentioned oversize versions, scrupulously executed and much too unwieldy for use. Their most prominent quality is symmetry in three dimensions. Such symmetry is an appealing form anywhere we see it—in faces, in animals (*Tiger, tiger, burning bright*), and in artifacts. It seems that early humans discovered and quickly perfected visual symmetry, sufficiently fascinated by the sublimation of form to invest in useless monuments to their own concinnity.

That isn't exactly to say they were designed, not in the full sense that characterizes technical culture since the Upper Paleolithic. By then, many tools are put together from many materials; they are specialized and regionalized, with variant forms for different ecologies; the sheer variety is unmatched in a hundred thousand years of modern human existence. Add these people's unprecedented cave painting and carving and it seems that by then a principle of design has penetrated artifice. Technics became designed, done by design, with style and ingenuity. Bringing in design makes artifice into a field of knowledge, understood in terms of superlative artifactual performance. Cultivating superlative performance in artifacts makes artifice more intelligent, the works looking (and being) more deliberate, intentional, thought-out, *designed.* The emergence of plastic arts, not the first stone tool, is the beginning of technical design and what eventually became engineering. Artful artifice and design are two effects and redescriptions of artifice reorganized as an economy of knowledge. Tools and painted or carved forms share in the design—the deliberate, trained, purposive, manual-mechanical intelligence—that the practice of knowledge brings to artifice. The birth of plastic art and the profound achievement of Paleolithic technics are not isolated incidents. They are two sides and verbal redescriptions of humanity's first sustained knowledge, couched in the dichotomy of a later age between art and technology.

We see ingenuity in works of art or technology when a seriously new alternative appears in design, whether aesthetic or technical, in a bridge or a painting. Ingenuity is a by-product of artifactual skill, or what I call technique (chapter 2). It's more than technique, though without technique there's no ingenuity.[46] "Serious" alternatives are ones that dramatically change the options—the rules of the game. Take for example Robert Maillart's idea for a deck-stiffened arch (figure 4.7).

The idea is to use the plastic quality of reinforced concrete to make the deck one continuous form with the arch. Instead of dead weight loading the arch, the road-deck actually stiffens it, making it stronger, therefore thinner, therefore cheaper to build. Thinner and stronger, stronger and cheaper, what used to be dead weight becomes a structural member supplying additional strength practically for free. That's a serious new alternative. The ingenuity goes further. If you had to trim off the "aesthetics" in Maillart's elegant bridge, what would you take away that wouldn't leave a ruin? What makes the bridge strong also makes it visually appealing. What makes it economical also makes it beautiful. Seldom is design more sublimely *art-technological*.

The ingenuity of technological design belongs with artistic ingenuity; for instance, the invention of Cubism. Picasso and Maillart are both designers of ingenious artifacts. Both are now widely imitated. Cubism's once startling visual ideas have been domesticated, while Maillart's ideas are ubiquitous in modern highways. A Cubist painting and a deck-stiffened arch are like a wheel or a clothes button—obvious once you see them, unimaginable the day before.[47] That's how innovations are. Nobody sees them coming, and then they seem inevitable. They so alter expectations that in time it's difficult to realize somebody had to invent these things.

The best work in engineering is a synthesis of anticipated perception and structural or mechanical invention, at once analytical and imaginative. Taking the comparison just that far, engineering would be indistinguishable from aesthetic design, or the idea of art. That idea is itself a technical idea, beginning in a *technical* breakthrough—finding ways to translate visual perception into a medium worked by the hands. I don't mean to say there's no difference between designing a painting and designing a bridge. One difference is that a painter like Picasso can design exclusively for aesthetic effect. The important effect of such design is its look—it works as designed if it captures and holds visual attention, motivating lingering and memory.

A bridge has to do more. But we shouldn't think a bridge has to *really work* in a way a painting doesn't (that *it*'s just play). True, the mechanical moment of making a painting is not as formidable as the aesthetic moment. It's not that hard (these days) to get paint to stay on canvas, or to get canvas, or paint. The challenge lies in the visual work, the aesthetic design. A bridge faces more stringent structural conditions than the relative effortlessness of putting paint on canvas. Designers have been tempted to make a beautiful bridge that is not strong, as at Tacoma Narrows, or to make indifferent or even ugly bridges because they're simpler or cheaper to build. Both are technical errors, bad engineering. That a bridge is bad that isn't strong may go without saying. It's no less true of an ugly bridge. There may be no danger of collapse, but it's likely to be overbuilt or

otherwise badly designed and therefore more expensive (not just in first costs) than it might have been if more care were spent on visual work.

When our ancestors began to cultivate knowledge the first thing they did was make works of art. So much for the idea that Technology is governed by instrumental rationality while Art is subjective whimsy or arbitrary social representation, or that artists are irrational dreamers and engineers artless technicians. This polarizing perspective clarifies nothing and is not reasonable. Enforcing purity, segregating art and technology into incommensurable categories of rationality and sentiment, divides us against ourselves, casting up self-made obstacles to a world that works.

# IN CONCLUSION

Am Ende hängen wir doch ab
Von Kreaturen die wir machten.

Goethe, *Faust*

Artifice is older than the arts of design, the plastic arts of drawing, painting, and sculpting, but the passage through these arts (their technical problems, especially how to imitate visual cues in different media) was decisive for the reorganization of technics as an economy of knowledge. We learned what design can do for artifice. The artistic accomplishment of Upper Paleolithic cave painting (figure 1.1) is a moment of a wider technical achievement that includes the design of tools, which become at once better engineered and more appealing to vision. The result is not technology right away, though in retrospect we can see that plastic art is a genealogical condition of modern science and technology. The art changes perception in a way all later sciences and technologies take for granted. It teaches vision to attend to and reproduce the look of its object. It practically discovers the "object," that is, something that just is (just looks) so. This objectivity is a matter of visual discipline, a technical art, and not a metaphysical discovery about being, or a transcendental presupposition of experience. Its possibility had to be discovered and cultivated, and that happened in visual art millennia before its manual-cognitive techniques were transferred to observational and experimental science.

I explained technology as an economic, threshold phenomenon. In a technological economy, machine-machine relations have become as productive as the

human interface. Artifice becomes more certain as relatively risk-free mechanisms replace the older workmanship of skill. Eventually, the larger part of production passes through a drawn-out design phase, orchestrating artifactual interfaces on many levels. The emergence of such an economy required many witless collaborators, but if it weren't for the plastic arts, there wouldn't have been technology. If it weren't for tools, there wouldn't be art. And if human hands weren't as they are (weren't as different as they are from ape hands), there wouldn't be tools. Hands point back to the evolution of the bipedal stance, which is a condition on brain evolution in species of *Homo*.[1] It is therefore unlikely that a species without primate bipedalism in its ancestry can have serious analogies to tools, technology, art, or knowledge.

The "well-known fact" that lots of animals (even insects!) use tools presupposes an objectionably simplistic concept of tool. I described chimpanzee "tools" as proto-tools. The difference between a proto-tool and a tool is how they become facilitating. Proto-tools are made of found material manipulated on the spot into a facilitating posture. Something that is not facilitating (a twig on a tree) is made to facilitate by an appropriate series of manipulations. That's what chimpanzees do when they make their insect lure, or use any other of their (proto-)tools. I located proto-tools at one end of a spectrum of manipulated facilitation; the other end shades off into the quasi-tools of birds and insects, which are very thin analogies to human tools (figure 2.3). Proto-tools differ from quasi-tools in degree of sphexishness. The species-specific use of a pebble to seal her burrow by the eponymous *Sphex ichneumoneus* is more sphexish—tropistic, unintelligent, without variation or individuality—than the population-particular proto-tool use of chimpanzees, who must individually learn their proto-tools, and show intelligent flexibility in application.

Human tools (really the only tools there are) do not appear on the continuum of manipulated facilitation. That's not how tools become facilitating. The use of a tool will, of course, require manipulation. The difference is that *what* we manipulate is not a found, unpremanipulated environment. It is a work, designed for functionality. Tools are charged with artificial functionality long before they are manipulated in use. They become facilitating not merely through manipulation but by prior, economically displaced artifice and design. Even primitive tools are already artifacts when users pick them up. Prior to use they are already socio-technical hybrids, black boxes enfolding multiplicities. This economic condition is not peculiar to advanced, modern, high technology. It has been a condition of technical culture, of the practice and economy of tools, ever since the beginning. A tool is a tool (and not a proto-tool) only if it is the product of other tools, other artifice, a unit of socio-technical economy.

The functionality of tools belies their lack of function. What tools "do" is reliably produce a range of results. What the reliable production of those results is

"good for," the tool's "function," depends entirely on the user. A tool is good for absolutely any function anyone wants to enroll it in. A bathtub, designed to produce certain results (watertight, commodious, fitting the back) still reliably produces those results long after it has been turned to bed clematis. Fitting a person's back is still reliably performed, precisely as designed, even though the certainty of that result has nothing to do with the tub's latest function.

Does that mean guns don't kill? They certainly facilitate lethal violence, a "function" men have cherished ever since they reinterpreted tools as weapons. Nevertheless, it's not the gun's function to kill. Its job, what it is designed to do, is reliably perform a highly controlled mechanical-ballistic effect. It does that regardless of the use or function of this functionality for a user. The shooter kills, and the gun collaborates, as does the economy that puts a gun in someone's hand, and the evolution that makes artificially amplified violence a resource. Everything is an accomplice after the fact. Guns give us purposes, making murderers of people who never would have been without them. But purposes also gave us guns in the first place. If a gun can make a killer, only a killer can make a gun.

Rather than think of art heroically—as an entity with an epic trajectory—I compare it to a biological genus. A genus like *Homo* or *Equus* embraces many species united by common ancestry rather than identity of form. A genus is not one thing, closed and finished, but neither is it an arbitrary, merely nominal unity. Its unity is evolutionary, descent with modification. Art seems like that. All the arts practiced over the world for the last thirty thousand years are like species in a profusely evolving genus. What makes all of it *art* is descent from a practice of aesthetic design, meaning design in anticipation of perception, artifice that works by appealing to the senses, especially vision and hearing.

The plastic arts of painting, drawing, and sculpture were probably invented more than once, just as agriculture, metallurgy, calendrics, writing, and urbanism arose independently several times around the world. My claim is that the historical core idea of "art" or "work of art" descends from a practice of designing for perception, aesthetic design for look and feel, and the accumulated discoveries of tradition. Drawing translates the work of the eyes into something made by hand, reconstructing vision right before your eyes. Stone Age cave painting is born of this technical translation across modalities—from conscious, second-order perception to manual technique; from the work of the eyes to the performance of the technically supplemented hand. This view of art is obviously most at home with the visual arts of painting and sculpture, where design begins its career, but I don't think it is limited to them. The first works of artful design may have been visual, but they inaugurate a principle of design—that the effectiveness (mechanical or perceptual) of works can be artfully amplified—which

may eventually reorganize anything whose presence and appeal can be enhanced by design.

Technical coherence (design) begins with aesthetic coherence (beauty), and never abandons it, even though modern technology puts the relationship under strain. There can be technically highly coherent artifacts without much aesthetic presence, whether because they are too small (a nanotechnological machine), or too vast (the North American electricity grid). Yet even these, because of their artifice, have to be constructed and maintained, and must therefore have a perceptual interface, even if it is diagrams. It is contemplating these, if at all, that we will feel the beauty of what we've made.

The aesthetically notorious bridges (chapter 4) are not perfectly good engineering that just happens to look atrocious. Their aesthetic failure cannot be distinguished from their technical flaws. Good engineering, good technical design, has two moments—structural-mechanical and aesthetic. Because we rely on how things look or feel to find technically good form. That's why drawing is long since indispensable. It's the best way we've found to anticipate the form of an object that does not yet exist. Nothing about "function" or the most efficient or economical means to an end can settle the shape or form of a work. Design has to be completed by second-order thinking about perception, guided by stylistic practice and aesthetic feeling. When these artistic skills are deficient (as in the notorious bridges) the result is bad engineering (figure 4.11). It may "work" (as tinned meat nourishes), but it cannot be the best work, or more than barely competent as engineering or technological design. Whether it's a bridge, tunnel, airplane, cabinet, sword, rifle, or mobile phone, nothing well made is free of aesthetic work on appearance. We don't know how to build *well* any other way.

Before Socrates, the famous Greek adage *gnōthi seauton* (know thyself!), ominously engraved over the entrance to Apollo's oracle at Delphi, meant know your place, your limits, your mortality. Approach the oracle with awe and dread of the immortal gods. Socrates ironically reinterpreted the saying as an injunction *against oracles,* enjoining us to look to ourselves for answers, to take our questions, our will to know, back *to ourselves.* Socratic self-knowledge is not introspective preoccupation with a private entity called self. I think of it as the sort of inquiry I called "philosophical anthropology" in my introduction. To know ourselves we must know what human beings are. We must know where they come from, their evolution. And we must know their form of life, their ecology, the terms on which they survive and flourish. Those terms are now agricultural, urban, and technological.

We have passed the point where these conditions are reversible. For instance, it would take a catastrophic depopulation to undermine urbanism as most people's

preferred way of life, something as likely to spiral into extinction as lead to non-urban forms of future humanity. But urbanism requires agriculture, and the more urban the world is, the more we rely on crops. Urban systems and civilizations do not have to use advanced technology, though once one of them does, it's difficult for others not to follow. We are therefore committed to living in cities as well as to an increasingly technological response to their cost. And that cost is severe. Cities are big parasites, always have been. Except now, the global urban network is practically coextensive with the *sapiens* ecology, upon which we act not as isolated communities but as a concerted planetary force.

We seldom give thought to the mechanisms we weave into our projects (how a car, computer, or mobile telephone works), even less to the real cost—the long-term ecological cost—of our conveniences. When a technical system comes into use and responds predictably it becomes a black box, something users interact with based on functionality. However, the veil falling over a reliable technology occludes more than its works, complications that may be of no concern to the user. It also hides the cost. The money price is as it were the screen memory of cost, something we fix on to avert our attention from cost, which remains invisible and unaccounted for.

We calculate prices to the penny, though few appreciate how a price is calculated, what is taken in or left out of account, or how these shiftless stratagems make the relation between cost and price practically arbitrary. A price in money is the real cost of a thing only on the obviously absurd assumption that nothing beyond the reach of bookkeeping matters to long-term human prosperity. Does the price of a Big Mac include the destruction of the Amazon rain forest (destroying trees to raise cattle to sell to the world's largest buyer of beef)? Does the price of a car include the cost of atmospheric warming or skin cancer for seven generations? Of course not. Yet these are real costs incurred against long-term human prosperity. Their relation to the price, which is all we care about, is *arbitrary*. Certainty about price displaces the imponderable uncertainties of cost in a way that is convenient but unethical. The determination of price entails accounting decisions about so-called externalities—those indispensable background conditions that entrepreneurs don't have to pay for, like air to breathe, rivers to carry away waste, or a literate labor force. But there never were any externalities, just economic shortsightedness, greed, and wishful thinking, a pattern we persist in as if the world were still new.

Since technology is all about design alternatives and technical options, it is ironic that the more connected, that is, technological, machines become, the fewer options we have at the highest levels of interaction. Technological choice is rich in risky side-effects opaque to prediction. Artifact-to-artifact interdependence has never been as deep or far-ranging, the systems never as tightly coupled, the

potential for unforeseen consequences never greater.[2] We have traded the advantages of variety and adaptability for tightly coupled, highly standardized technological systems, those precisely most vulnerable to unpredictable consequences.

Our own artifacts, especially technological artifacts, are now the world's leading source of ecological uncertainty. That is an ironic outcome, if a plausible theory on the evolution of culture is right. In this theory, culture evolved as an adaptation to rapidly changing environments. The ecological context of evolution throughout the *Homo* genus is not "savannah" as a new status quo after the retreat of the jungle in the last Ice Age. Our entire evolution as a genus occurs in a context of dramatic climate instability. Africa was for this whole period vulnerable to sudden, decade-scale climatic change. There is evidence of many occasions (dozens) of global climate shift from cool-dry to warm-wet occurring within decades. Species that shared African habitat with *Homo* found other ways to deal with the uncertainty. Some evolved variable developmental programs that set ontogeny on a different course depending on natal conditions (wet/warm, dry/cool, and so on). Culture—artifacts and their economy—was the *Homo* solution to the challenge of uncertainty.[3]

Culture—true social learning and accumulating artifice—allows people to innovate largely new ways of making a living in a single generation if they have to. Unlike natural selection, which merely eliminates what doesn't work, variation by imitation-plus-modification creates new artifacts that can be subjected to the same process again, gradually advancing competence and flexibility. Technical variation comes under purposive control and is no longer a matter of chance. Ecological boom-and-bust cycles drive a gradually accumulating body of culture (artifacts and their practice), as evolving human groups struggle to survive climatic catastrophe, a process neatly described as "catastrophic gradualism pumped by climatic instability."[4]

That was obviously a good trick for hominid survival in prehistoric Africa, but things have changed. Now it's culture itself—or a particular culture, our modern technological civilization—and not a formerly independent variable like climate, that is the source of uncertainty. The behaviors (like niche-thieving) that gave humans unparalleled adaptability now threaten our survival. That includes technology. The greater our commitment to technological mediation, the greater the long-term ecological uncertainty of technologically mediated action. Science does not hold the solution to this uncertainty. There is no solution—at best there is a modus vivendi, an ethos, an ethics of technological civilization. The uncertainty of technically mediated action is an ethical problem and calls for an ethical response, which has to respect uncertainty instead of making it invisible. Ethics is not about *knowing* the right, not about acting with certainty. It is about caring for the right, which means respecting its uncertainty and caring about the hidden

harms of action. For the most important knowledge is knowing what we do not know.[5]

Turning away from technology is not a serious option, of course. Turning away, or trying to, would be as dangerous as anything else we might do, including nothing at all. It seems obvious that the only solution to the problems of technological ecology is better technology. What may be less obvious is that "better" should be understood aesthetically, and technological design (engineering) practiced more artfully. The more complete and profound the conception of a technical problem, the more design approaches the conditions of art. Not "fine art," but working art, artful works, artistry in artifice, *poiesis* in the double sense of poetry and production, the *poiesis* of design, whether in a ship or a sonnet.

I think a technology that was "better" in that respect would be one that is more *intensely* and more *profoundly* technological. So that I'm not misunderstood (for instance, as advocating a "technical fix for the problems of technology") I'd like to recall some conclusions of this book: that technology is a socio-technical economy of acts and artifacts; that tools are quasi-social collaborators, and instrumental cognition at once technical and social; that there is no "one best way," no purely instrumental rationality, no logic of design; and that the aesthetic moment cannot be eliminated from technological design without undermining the best work. We settle for less but it's costing us more.

A more intense technology would require engineering to become more serious about the ecological effects of its works, including how to recycle them and what they work with. Technologists need to think more systematically about the side-consequences and by-products of their works, and of the day when the work no longer works as designed and has to be, not trashed, but retired and recycled. It seems to me that the engineering profession might more enthusiastically and ingeniously cooperate with this alternative. Why can't engineering be expected to maximize recycling just as it's expected to maximize efficiency, when it's the same demand on a more realistic time scale? Environments, ecologies, the future—these are not cost-free "externalities," not for economics or engineering. They should be part of any design problem, and would be if technological design were practiced with greater intensity, meaning that the engineering did not stop with first use, that works remain in the technical economy (rather than the trash) because they are *designed* for multiple recycling.[6]

A more profound technology would more consistently take on art's concern for the perceptual interface of artifice. Engineering cannot be as good as we need it to be if it fails to grasp its technical problems as ultimately problems of art. Fully engaged technical thinking can be at once aesthetic and mechanical. Devices often don't work, or don't work as well as they could, unless both these moments of the design problem are taken into account. Art begins with attention to the look

and feel of things we make, and the more art cares for the better the built world. Art may potentially work at any point of the perceptual interface with artifice. That's why a more profound technology would be a more artful one. The knowledge of design and artifice would be applied to make works appealing at every interface with perception, and would foresightedly anticipate side-consequences and problems of reuse. Ideally, that means any interaction with technology is at least civil, if not appealing, delightful, awesome, or in some perhaps presently unknown way beautiful.

Ineluctably technological societies like ours should be aesthetically more discerning about technology. Bad work, ugly work, cheap-and-dirty work are becoming simply too expensive, especially if we count costs and not just prices. Many of the rising problems of technological ecology (not least trash) are due to the extraordinary rapidity of technological change, which must say more about greed than need. Bruno Latour thinks change goes so fast because we have settled into a set of dichotomies that make it difficult to represent the kind of process technological change actually is. Primarily, the dichotomy between Nature and Society. According to this way of thinking, Technology is Nature—physics; what we do with it is Society, Culture, Politics.[7] Technology is just a fact, a discovery, a purely external relation whose application awaits cultural evaluation. Latour sees an injustice in these dualisms. They make technological change out to be a purely social matter, something for human beings to work out among themselves, with no voice for the nonhuman artifacts who do most of the work.

Latour thinks nonhuman hybrids matter too materially not to be represented. Bringing them (and the engineers and scientists who speak for them) into deliberation should enhance democracy. More of the "actants" actually doing the work of technological civilization would be explicitly consulted in deliberation on a common future. It makes democracy more complicated, but that's all right. Latour would like to see us "change our way of changing," change the rhythm and ethos of technological change.[8] More consistent democracy would slow the proliferation of technoscientific hybrids, which must become more difficult as consultation is less constrained and deliberation more circumspect. In this way, a modification of institutions and expectations that makes our civilization more consistently democratic would also address the challenges of technological ecology.

To extend this argument in a direction Latour has not explored, I'm suggesting that a more democratic technoscientific civilization would allow, even expect, a more artful, aesthetic approach to technology, overcoming obstacles to engineering being as artistic as it can. Because change slows down, is less frenetic, more deliberate and democratic, there is no reason not to widen potentially any technological design problem to the level of art and the aesthetics of a work's place

in the built world and artifactual ecology. Design on such principles would work over every perceptual interface. The work would (ideally) never turn a mean, ugly, cheap, careless face to any who cross paths with it. It would exemplify the practice of design as an ethical art. Technological change will never be as democratic as it might until technological design is as artistic as it can be.

I have no predictions to make about the Western fine-arts traditions in painting, sculpture, and so on. I do think the whole idea of "the fine arts" is on shaky ground. I'm skeptical of the rationalism that carefully distinguishes Art from Science, Beauty from Truth, or Aesthetics from Technology, and some few special Fine Arts from the rest of what used to be called *ars* and *techne,* the arts and knowledges of technical culture. However, what I've called *the idea of art,* by which I mean the cultivation of aesthetic design, with its attention to the human, perceptual interface with artifice, has a hopeful future if there's a hopeful future at all.

There is something impressively humane about the practice of art. It cultivates care for the look and feel of things, and works to make a shared world agreeable through well-made works. The practice of art humanizes because its work creates perceptual appeal across the full range of the human interface, everywhere works touch us or make a difference to our experience. We cannot flourish as a technological civilization without also flourishing as an artistic one. If we try to manage the technology (take it where we think we want to go) without the art, we undermine both, and everything that depends on them, which is nothing less than the future. I don't know if that's why you chose to read a book about the philosophy of art and technology, but it's why I wanted to write one.

# NOTES

## Introduction

1. There is but one such book to my knowledge, now rather dated and philosophically at odds with my approach: Lewis Mumford, *Art and Technics* (New York: Columbia University Press, 1952).

2. That was also Socrates' point of view (despite Plato's orchestrated refutation of Protagoras). "The only universe he knows," Ernst Cassirer observes of Socrates, "and to which all his inquiries refer, is the universe of man. His philosophy—if he possesses a philosophy—is strictly anthropological." Socrates tells how he turned away from the Ionian philosophers of nature, with their search for impersonal cosmological law; how he took up moral concerns, ethics, the soul, the good. He says, "I am still unable, as the Delphic inscription orders, to know myself; and it really seems to me ridiculous to look into other things before I have understood that." Ernst Cassirer, *An Essay on Man* (New Haven: Yale University Press, 1944), 4; and Socrates, in Plato, *Phaedrus,* trans. Paul Woodruff and Alexander Nehamas, in Plato, *Complete Works,* ed. John M. Cooper (Indianapolis: Hackett, 1997), 229–230. Putting *anthropos* at the center obviously makes philosophy anthropocentric. Some consider that an objectionable elevation of humanity but I am unapologetic. The lineage of anthropocentric philosophy includes Protagoras, Socrates, Epicurus, Montaigne, Vico, Montesquieu, Rousseau, Diderot, Herder, and Nietzsche—decent company for philosophers. No transcendental missionaries among them, no puritanical Platonists or Cartesian cravers of the invincibly certain. The idea of a morally objectionable "anthropocentrism" seems to begin with Ernst Haeckel at the end of the nineteenth century. He called it anthropism, "that powerful and world-wide group of erroneous opinions which opposes the human organism to the whole of the rest of nature, and represents it to be the preordained end of the organic creation, an entity essentially distinct from it, a godlike being." *The Riddle of the Universe,* trans. Joseph McCabe (1899; Buffalo: Prometheus Books, 1992), 11. That is far from the view of Protagoras, as well as from my own, which has no use for a dichotomy between "human" and "nature," nor for preordained ends or godlike beings.

3. This is not an argument original to me. Arnold Pacey, *The Culture of Technology* (Cambridge: MIT Press, 1983), and in a complementary way George Basalla, *The Evolution of Technology* (Cambridge: Cambridge University Press, 1988), refute the idea that technology follows a smooth (and inevitable) path of advance, or has any reality apart from the social contexts in which it is embedded. The latter point is emphasized in Marcia-Anne Dobres, *Technology and Social Agency* (Malden, Mass.: Blackwell, 2000); and Andrew Feenberg, *Questioning Technology* (London: Routledge, 1999). Science and Technology Studies have added a lot of evidence to the argument, which is probably now generally accepted among scholars, if not

the wider public. See for instance W. E. Bijker et al., eds. *The Social Construction of Technological Systems* (Cambridge: MIT Press, 1987); John Law, ed., *A Sociology of Monsters: Essays on Power, Technology, and Domination* (London: Routledge, 1991); John Law, *Aircraft Stories: Decentering the Object in Technoscience* (Durham: Duke University Press, 2002); and Andrew Feenberg and Alastair Hannay, eds., *Technology and the Politics of Knowledge* (Bloomington: Indiana University Press, 1995). The contingency and even arbitrariness of technological history is a theme of Lynn White, Jr., *Machina Ex Deo: Essays in the Dynamism of Western Culture* (Cambridge: MIT Press, 1968); Robert McCormick Adams, *Paths of Fire: An Anthropologist's Inquiry into Western Technology* (Princeton: Princeton University Press, 1996); Nathan Rosenberg, *Exploring the Black Box: Technology, Economics, and History* (Cambridge: Cambridge University Press, 1994); Pierre Lemonnier, *Elements for an Anthropology of Technology* (Ann Arbor: Museum of Anthropology, University of Michigan, 1992); Bruno Latour, *Aramis, or the Love of Technology,* trans. Catherine Porter (Cambridge: Harvard University Press, 1996); and Merritt Roe Smith and Leo Marx, eds., *Does Technology Drive History?* (Cambridge: MIT Press, 1994).

4. On the mythical purity of inhuman objectivity in science and technology as an obstacle to democracy, see Bruno Latour, *Politics of Nature: How to Bring the Sciences into Democracy,* trans. Catherine Porter (Cambridge: Harvard University Press, 2004).

## 1. The Human

1. See the work collected in *The Adapted Mind: Evolutionary Psychology and the Generation of Culture,* ed. Jerome H. Barkow, Leda Cosmides, and John Tooby (Oxford: Oxford University Press, 1992). On difficulties for adaptationist theories of brain evolution, see Christopher Badcock, *Evolutionary Psychology* (Cambridge: Polity Press, 2000), 29–36.

2. Charles Darwin, *The Descent of Man,* in *The Origin of Species and The Descent of Man* (New York: Modern Library, 1936), 441, 442.

3. See Steven Jay Gould, *The Structure of Evolutionary Theory* (Cambridge: Harvard University Press, 2002), chap. 11.

4. Jonathan Kingdon, *Lowly Origin: Where, When, and Why Our Ancestors First Stood Up* (Princeton: Princeton University Press, 2003), 40; Spencer Wells, *The Journey of Man* (New York: Random House, 2003), 43. On the microbial phase of life, see Lynn Margulis and Dorion Sagan, *Acquiring Genomes: A Theory of the Origins of Species* (New York: Basic Books, 2002).

5. Sometimes needlessly qualified as *H. sapiens sapiens.* The point of the qualification was to distinguish us from Neanderthal at a time when it was believed to be related to us as a subspecies, a hypothesis now disproved by microbiology.

6. This first *Homo* species, which was also the first to make stone tools, used to be identified with the *Homo habilis* fossils discovered by Mary Leakey in 1961. The *habilis* species is now in doubt; see Richard G. Klein, *The Human Career: Human Biological and Cultural Origins* (Chicago: University of Chicago Press, 1989), 158, 403; and Richard G. Klein and Blake Edgar, *The Dawn of Human Culture* (New York: Wiley, 2002), 82–85. Steven Stanley makes the case for *H. rudolfensis* as the incipient species of the *Homo* genus and maker of the Oldowan tools; see *Children of the Ice Age* (New York: W. H. Freeman, 1998). However, there may be an emerging consensus that *H. rudolfensis* be reclassified as Australopithecine, with *H. ergaster* as the earliest known *Homo.* See B. A. Wood, "History of the Genus *Homo,*" *Human Evolution* 15 (2000): 39–49; and L. C. Aiello and P. Andrews, "The Australopithecines in Review," in *The Human Evolution Source Book,* ed. Russell L. Ciochon and John G. Fleagle, 2d ed. (Upper Saddle River, N.J.: Pearson Prentice Hall, 2006).

7. Kingdon, *Lowly Origin,* 234, 241.

8. See David W. Cameron, *Hominid Adaptations and Extinctions* (Sydney: University of New South Wales Press, 2004); and Pamela R. Willoughby, *The Evolution of Modern Humans in Africa* (Lanham: AltaMira Press, 2007).

9. Imprecise because bipedalism evolved independently of hominids at least once. We have a primate ancestor (*Oreopithecus bambolii,* 7–9 million years ago) that, though bipedal, lies off the line that links the early hominids to the later species of *Homo* and to ourselves. Paul R. Ehrlich, *Human Natures: Genes, Cultures, and the Human Prospect* (New York: Penguin, 2002), 359.

10. I summarize from Kingdon, *Lowly Origin,* 5, 222, 238, 247, 257, 348–49, 351–52, 367. On bipedalism, see also Owen Lovejoy, "Evolution of Human Walking," in Ciochon and Fleagle, *Human Evolution Source Book.*

11. On *H. sapiens* dating from about 160,000 years ago, see M. Ingman et al., "Mitochondrial Genome Variation and the Origin of Modern Humans," *Nature* 408 (2000): 708–13; T. D. White et al., "Pleistocene *Homo sapiens* from Middle Awash, Ethiopia," *Nature* 423 (2003): 742–47; L. L. Cavalli-Sforza, *Genes, People, and Language* (New York: North Point Press, 2000); and T. R. Disotell, "Origins of Modern Humans Still Look Recent," *Current Biology* 9 (1999): 647–50.

12. Wells, *Journey of Man,* 77–80, 98, 139, 64, 69. Mungo Lake humans, 62,000 ± 6,000 years old; see C. B. Stringer, "Modern Human Origins," in Ciochon and Fleagle, *Human Evolution Source Book.* According to Kingdon, *H. erectus* was using watercraft in Indonesia 800,000 years ago (*Lowly Origin,* 279).

13. Wells, *Journey of Man,* 59, 120, 191, 133, 134, 191. On "races" see also Willoughby, *Evolution of Modern Humans,* 159–160; and A. R. Templeton, "Human Races," *American Anthropologist* 100 (1998): 632–50, who argues that there is only one evolutionary lineage of humanity and no races in either the traditional subspecies or evolutionary understanding of the idea.

14. On the science of human-chimp genetic comparison, see Vincent Sarich and Alan Wilson, "Immunological Time Scale for Hominid Evolution," *Science* 158 (1967): 1200–1203; and Charles Sibley and Jon Ahlquist, "DNA Hybridization Evidence of Hominoid Phylogeny," *Journal of Molecular Evolution* 26 (1987): 99–121.

15. Jonathan Marks, *What It Means to Be 98% Chimpanzee* (Berkeley: University of California Press, 2003), 13. I also draw from pages 5, 28, 29.

16. Charles Sibley, quoted in Delta Willis, *The Hominid Gang* (New York: Viking Penguin, 1989), 289.

17. George C. Williams, *Plan and Purpose in Nature* (London: Weidenfeld & Nicolson, 1996), 45.

18. The claim that a 2 percent genetic difference can be so apportioned as to change every one of our genes is made by Ehrlich, *Human Natures,* 354; and Steven Pinker and Paul Bloom, "Natural Language and Natural Selection," in Barkow et al., *Adapted Mind,* 485.

19. See Jason Robert, *Embryology, Epigenesis, and Evolution: Taking Development Seriously* (Cambridge: Cambridge University Press, 2004).

20. José Saramago, *Blindness,* trans. Giovanni Pontiero (San Diego: Harcourt, 1997).

21. My discussion draws from John Napier, *Hands,* rev. ed. (Princeton: Princeton University Press, 1993); Erik Trinkhaus, "Evolution of Human Manipulation," in *The Cambridge Encyclopedia of Human Evolution,* ed. S. Jones, R. Martin, and D. Pilbeam (Cambridge: Cambridge University Press, 1992); Françoise K. Jouffroy, "Primate Hands and the Human Hand"; Roger Lemon, "Control of Monkey's Hand by Motor Cortex"; and Jacques Paillard, "The Hand and the Tool: The Functional Architecture of Human Technical Skills," all in *The Use of Tools by Human and Nonhuman Primates,* ed. Arlette Berthelet and Jean Chavaillon (Oxford: Clarendon Press, 1993); Russell H. Tuttle, "Hands from Newt to Napier," in *Topics in Primatology,* vol. 3, ed. Shozo Matano (Tokyo: University of Tokyo Press, 1992); C. G. Phillips, *Movements of the Hand* (Liverpool: Liverpool University Press, 1986); Christine L. MacKenzie and Thea Iberall, *The Grasping Hand* (Amsterdam: North-Holland, 1994); Raymond Tallis, *The Hand: A Philosophical Inquiry into Human Being* (Edinburgh: University of Edinburgh Press, 2003); and Frank R. Wilson, *The Hand* (New York: Vintage, 1998).

22. K. P. Oakley, "Skill as a Human Possession," in *A History of Technology,* vol. 1, ed. Charles Singer, E. J. Holmyard, and A. R. Hall (Oxford: Oxford University Press, 1954), 10–12. Technically, brachiation is an arboreal progression, swinging from branch to branch by the arms, to the exclusion of running and leaping, and is peculiar to apes. All monkeys make incidental use of such movement but only apes are full brachiators when in trees, for which they have developed "functional and structural adaptations of a far-reaching type." Wilfrid E. Le Gros Clark, *The Antecedents of Man* (Edinburgh: University of Edinburgh Press, 1959), 50–51, 202–3. On the diversity of primate hand anatomies, as well as haptic perception in nonhuman primates, see Agnès Lacreuse and Dorothy M. Fragaszy, "Tactile Exploration in Nonhuman Primates," in *Touching for Knowing: Cognitive Psychology of Haptic Manual Perception,* ed. Yvette Hatwell, Arlette Streri, and Edouard Gentaz (Amsterdam: John Benjamins, 2003).

23. Napier, *Hands,* 25.

24. The singularity of a human hand is not merely an opposable thumb but equally our so-called ulnar

opposition, flexing fingers on the ulnar side of the hand (side with the little finger) toward the base of the thumb. This movement, which among contemporary primates is unique to humans, enables precise throwing, vicious clubbing, and an enhanced precision grip. Wilson, *The Hand,* 27–28.

25. This is a major argument of Tallis, *The Hand.*

26. The experiments are described in M. A. Goodale, D. Pélisson, and C. Prablanc, "Large Adjustments in Visually Guided Reaching," *Nature* 320 (1986): 748–50; A. D. Milner and M. A. Goodale, *The Visual Brain in Action* (Oxford: Oxford University Press, 1995); James T. Enns, *The Thinking Eye, the Seeing Brain* (New York: Norton, 2004), 355, 368–69; Tallis, *The Hand,* 59; and Arlette Streri, "Intermodal Relations in Infancy," in Hatwell et al., *Touching for Knowing.* On Sherrington, Wilson, *The Hand,* 97.

27. Walter Chrysler is cited from Eugene S. Ferguson, *Engineering and the Mind's Eye* (Cambridge: MIT Press, 1992), 50. James Nasmyth is cited from Henry Petroski, *Remaking the World* (New York: Vintage, 1997), 36. See also Bruno Latour, "Visualization and Cognition: Thinking with Eyes and Hands," *Knowledge and Society* 6 (1986): 1–40.

28. On the cinematographic analysis of action, see Dennis H. Holding, ed., *Human Skills* (Chichester: J. Wiley, 1981), 53.

29. Tallis, *The Hand,* 187, 191. I also draw from Andy Clark, *Being There* (Cambridge: MIT Press, 1997), 45. On the mystery of *practice makes perfect,* see Wilson, *The Hand,* chap. 5. For more evidence against the "motor program" idea of technical action see David Sudnow, *Ways of the Hand: The Organization of Improvised Conduct* (London: Routledge & Kegan Paul, 1978); and Gabor Csepregi, *The Clever Body* (Calgary: University of Calgary Press, 2006).

30. William H. Calvin, *A Brain for All Seasons: Human Evolution and Abrupt Climate Change* (Chicago: University of Chicago Press, 2002), 76.

31. I summarize from Frederick Turner and Ernst Pöppel, "Metered Poetry, the Brain, and Time," in *Beauty and the Brain: Biological Aspects of Aesthetics,* ed. Ingo Rentschler, Barbara Herzberger, and David Epstein (Basel: Birkhäuser Verlag, 1988), 72–76.

32. Peter J. Bowler, *Evolution: The History of an Idea,* 3d ed. (Berkeley: University of California Press, 2003), 213. I also draw from Ehrlich, *Human Natures,* 125; and Peter C. Reynolds, *On the Evolution of Human Behavior* (Berkeley: University of California Press, 1981), 81. Brain growth is allometrically disproportionate to body size in several species, including the otherwise inconspicuous echidna (*Tachyglossus aculeatus*), a marsupial anteater whose prefrontal cortex occupies 50 percent of the whole cortex, more than any other animal, humans included. See Badcock, *Evolutionary Psychology,* 33; and E. Clark, *In Search of Human Nature* (London: Routledge, 2002), 136.

33. This is the argument of Robin Dunbar, *Grooming, Gossip, and the Evolution of Language* (Cambridge: Harvard University Press, 1996).

34. See Michael L. McKinney, "Brain Evolution by Stretching the Global Mitotic Clock of Development," in *Human Evolution through Developmental Change,* ed. Nancy Minugh-Purvis and Kenneth McNamara (Baltimore: Johns Hopkins University Press, 2002). This conclusion revises Steven Jay Gould's theory that neoteny, or the retention of juvenile characteristics, is the developmental peculiarity of human beings, which is his argument in *Ontogeny and Phylogeny* (Cambridge: Harvard University Press, 1977).

35. Scott F. Gilbert, "Genetic Determinism," in *On Human Nature: Anthropological, Biological, and Philosophical Foundations,* ed. A. Grunwald, M. Gutmann, and E. M. Neumann-Held (Berlin: Springer, 2002), 131. The claim that there are no new neurons after maturity is refuted; see Melvin Konner, *The Tangled Wing,* 2d ed. (New York: Henry Holt, 2002), 69.

36. I draw from D. E. Berlyne, *Aesthetics and Psychobiology* (New York: Appleton-Century-Crofts, 1971), 107–14, 181–85; and Antonio Damasio, *Looking for Spinoza: Joy, Sorrow, and the Feeling Brain* (Orlando: Harcourt, 2003), 93.

37. Rudolf Arnheim, *Toward a Psychology of Art* (Berkeley: University of California Press, 1966), 33. There has never been a nonabstract painting, "nonmimetic art does what art has always done." *Art and Visual Perception,* rev. ed. (Berkeley: University of California Press, 1974), 461.

38. Enns, *Thinking Eye,* 9, 11, 12, 165–66; Robert L. Solso, *Cognition and the Visual Arts* (Cambridge: MIT Press, 1994), 22–25; and Arnheim, *Art and Visual Perception,* 43.

39. Rudolf Arnheim, *Visual Thinking* (Berkeley: University of California Press, 1969), 24; I also draw from pages 14, 20, 21–22.

40. See Michael Tomasello and Josep Call, *Primate Cognition* (Oxford: Oxford University Press, 1997).

41. The research behind these claims is summarized in Steven Pinker, *The Blank Slate: The Modern Denial of Human Nature* (New York: Penguin, 2002), 63; and Tomasello and Call, *Primate Cognition,* 405.

42. Tomasello and Call, *Primate Cognition,* 416, 407, 422, 424. In philosopher Kim Sterelny's epitome, chimpanzees are socially savvy without being psychologically savvy. *Thought in a Hostile World: The Evolution of Human Cognition* (Malden, Mass.: Blackwell, 2003), 57–58. To say we *savvy* others psychologically is not to claim that our understanding of others has the character of a so-called theory of mind. The understanding is not "theory-like," and may depend on context-sensitive cues like expression and posture reliably supplied by cooperative adults, who also tell stories replete with interpretations of others. Sterelny, *Thought in a Hostile World,* 218–23.

43. I draw on George Butterworth, "Pointing Is the Royal Road to Language for Babies," in *Pointing: Where Language, Culture, and Cognition Meet,* ed. Sataro Kita (Mahwah, N.J.: Lawrence Erlbaum, 2003); and Michael Tomasello, *The Cultural Origins of Human Cognition* (Cambridge: Harvard University Press, 1999), 62–70. Use of some part of the body to point seems to be a human universal, though apparently not the use of the index finger. Some aspects of pointing may be shared with other primates, though there are many differences; see Daniel J. Povinelli, Jesse M. Bering, and Steve Giambrone, "Chimpanzee Pointing," in Kita, *Pointing.*

44. Stanley I. Greenspan and Stuart G. Shanker, *The First Idea: How Symbols, Language, and Intelligence Evolved from our Primate Ancestors to Modern Humans* (Cambridge: Da Capo, 2004), 29, 30, 31, 36–37.

45. Tomasello, *Cultural Origins,* 7, 120, 123, 126, 179. On the greater importance of ongoing adjustment over formal structure in the use of language, see Donald Davidson, "What Metaphors Mean," in *Inquiries Concerning Truth and Interpretation* (Oxford: Oxford University Press, 1984); and "A Nice Derangement of Epitaphs," in *Truth and Interpretation,* ed. Ernest LePore (Oxford: Blackwell, 1986).

46. Sterelny, *Thought in a Hostile World,* 145.

47. Tomasello, *Cultural Origins,* 16–18, 23, 24, 183.

48. See Elizabeth V. Spelman, *Repair: The Impulse to Restore in a Fragile World* (Boston: Beacon Press, 2002).

49. Networks of humans and nonhumans is an important idea in Bruno Latour's work; see *Pandora's Hope: Essays on the Reality of Science Studies* (Cambridge: Harvard University Press, 1999), chap. 6.

50. Sterelny, *Thought in a Hostile World,* 19.

51. Merlin Donald, *Origins of the Modern Mind* (Cambridge: Harvard University Press, 1991), 382, 312.

52. Turner and Pöppel, "Metered Poetry, the Brain, and Time," 71–90.

53. Ibid., 80–81, 84.

54. Latour, "Visualization and Cognition," 16; and Patrick Maynard, *The Engine of Visualization* (Ithaca: Cornell University Press, 1997), 145.

55. I'm summarizing an argument from Maynard, *Engine of Visualization,* 140–41. On ultrasound imaging, see also Barbara Duden, *Disembodying Women,* trans. Lee Hoinacki (Cambridge: Harvard University Press, 1993).

56. I draw from James R. Hurford, "The Evolution of Language and Languages," in *The Evolution of Culture,* ed. Robin Dunbar, Chris Knight, and Camilla Powers (New Brunswick: Rutgers University Press, 1999), 180–83.

57. Darwin, *Descent of Man,* 464. In fancier terms, "Language shows signs of design for the communication of propositional structures over a serial channel." Pinker and Bloom, "Natural Language and Natural Selection," 459. Darwin does not pursue this theory in *Descent of Man.* When he returns to the origin of language in his next book (originally planned as part of *Descent*), the theory is different, tracing speech back to emotionally expressive vocalization. Charles Darwin, *The Expression of the Emotions in Man and Animals,* 3d ed. (Oxford: Oxford University Press, 1998), 92.

58. See Derek Bickerton, *Language and Species* (Chicago: University of Chicago Press, 1990); and "How Protolanguage Became Language," in *The Evolutionary Emergence of Language,* ed. Chris Knight, Michael Studdert-Kennedy, and James Hurford (Cambridge: Cambridge University Press, 2000), 264–84; also Philip Lieberman, *Eve Spoke: Human Language and Human Evolution* (New York: Norton, 1998), 8.

59. This précis of protolanguage draws from Derek Bickerton, *Language and Human Behavior* (Seattle: University of Washington Press, 1995), 29–31, 71; and *Language and Species,* 122–26.

60. See Bernard Comrie, "Before Complexity," in *The Evolution of Human Languages,* ed. John

Hawkins and Murray Gell-Mann (Reading, Mass.: Addison-Wesley, 1992), 210; and Bickerton, *Language and Species,* 180.

61. On off-line thinking, see Clark, *Being There,* 210; and Bickerton, *Language and Human Behavior,* 56, 59, 90. Neurologically, this cognitive mode depends on the neocortex, and supports some of the cognition required for tool use, like tuning out interference, inhibiting immediate reaction, facilitating concentration, organizing temporal planning, and focusing shared attention on an object. See Jacques Paillard, "Hand and Tool," in Grunwald et al., *On Human Nature.*

62. Berlyne, *Aesthetics and Psychobiology,* 122. Such behavior in the theater is not a myth. Here is an example from early twentieth-century Japan, told by a resident British observer. It concerns "a Japanese friend" who "had traveled in Europe and America, spoke perfect English and wore foreign clothes every day." The Japanese friend was invited as a journalist to "attend a gala performance at the Kabukiza, the principal theater of the metropolis [Tokyo], where the late Danjuro, Japan's most famous modern actor, was cast for the leading role—the impersonation of a former Shogun. My friend, whom I shall call Mr. S, arrived in good time and occupied his box. All went well until the entrance of the star and then, carried away by the intense realism of the production, and more especially by the majesty of Danjuro's appearance and address as he stalked toward the footlights, poor Mr. S forgot that it was all make-believe and made a profound obeisance in his box and in the direction of the great actor! His feelings when he realized what he had done may be readily imagined. That he, a samurai, should have thus demeaned himself in honour of a plebeian and a member of the despised class of Thespians at that, was none too pleasant a reflection, and the 'noisy laugh and ill-bred chaff' of his many male friends did not help to mend matters." E. J. Harrison, *The Fighting Spirit of Japan* (Woodstock, N.Y.: Overlook Press, 1982), 206.

63. My summary of this evidence draws from Michael C. Corballis, *From Hand to Mouth: The Origins of Language* (Princeton: Princeton University Press, 2002), 46–48, 53, 63–64, 149. See also Greenspan and Shanker, *First Idea,* 163–65; and D. F. Armstrong, W. C. Stokes, and S. Wilcox, *Gesture and the Nature of Language* (New York: Cambridge University Press, 1995).

64. Robert R. Povine, *Laughter: A Scientific Investigation* (New York: Viking, 2000), 79–88. Fine control of breath depends on a fan of chest muscles, the Serratus complex. In quadrupeds these muscles serve suspension, attaching the top of the shoulder blade to the ribs. Bipedalism released these muscles and permitted their enrollment in control of breathing, a precondition of speech (Kingdon, *Lowly Origin,* 267).

65. ASL equivalents of Broca/Wernicke aphasias are produced by the same or similar lesions. Learning schedules for sign by deaf children replicate those of children learning speech. Wilson, *The Hand,* 200.

66. That is the argument of my *Knowledge and Civilization* (Boulder: Westview Press, 2004), where I also discuss other topics only lightly touched on in this section, including the relationship between knowledge and truth and the idea of superlative artifactual performance. See also my "Turning Back the Linguistic Turn in the Theory of Knowledge," *Thesis Eleven* 89 (2007): 6–22; and "Knowledge," *New Dictionary of the History of Ideas,* ed. Maryanne Cline Horowitz (Detroit: Charles Scribner's Sons, 2005), 3:1199–1204.

67. Keith Lehrer, *Theory of Knowledge* (Boulder: Westview Press, 1990), 3.

68. I discuss Nietzsche's ideas about knowledge in *Knowledge and Civilization,* chap. 3.

69. See my *Truth in Philosophy* (Cambridge: Harvard University Press, 1993).

70. On transitive and intransitive expression, see Alan Tormey, *The Concept of Expression* (Princeton: Princeton University Press, 1971). Darwin discusses transitive expressive behavior across the animal kingdom in *Expression of Emotions in Man and Animals.*

71. Good overviews of Upper Paleolithic culture are John Pfeiffer, *The Creative Explosion: An Inquiry into the Origins of Art and Religion* (Ithaca: Cornell University Press, 1982); Klein and Edwards, *Dawn of Human Culture;* and Steven Mithen, *The Prehistory of the Mind* (London: Thames and Hudson, 1996). For a technical update, see *The Early Upper Paleolithic beyond Western Europe,* ed. P. Jeffrey Brantingham, Steven L. Kuhn, and Kristopher W. Kerry (Berkeley: University of California Press, 2004). There were still Neanderthal in Spain (Zafarrya) as late as 28,000 years ago. See James Shreeve, *The Neandertal Enigma* (New York: Avon, 1995), 342.

72. The Paleolithic pedigree of dogs is disputed. See P. S. C. Taçon and C. Pardoe, "Dogs Make Us Human," *Nature Australia* 27 (2002): 52–61; and for skepticism, Raymond Coppinger and Lorna Coppinger, *Dogs* (Chicago: University of Chicago Press, 2001), chap. 10.

73. This was my argument in *Knowledge and Civilization,* which I am now qualifying in light of the Middle Stone Age evidence, especially as presented in Sally McBrearty and Alison S. Brooks, "The Revolution That Wasn't: A New Interpretation of the Origin of Modern Human Behavior," *Journal of Human Evolution* 39 (2000): 453–563.

74. See McBrearty and Brooks, "The Revolution That Wasn't"; and O. Bar-Yosef and S. L. Kuhn, "The Big Deal about Blades," in Ciochon and Fleagle, *Human Evolution Source Book.* The discovery in 1995 at Schöningen, Germany, of a cache of wooden spears 400,000 years old is the earliest evidence anywhere of equipment specifically for hunting large game. Wooden tools with hafted stone blades at the same site are the oldest composite tools. *The Hominid Individual in Context,* ed. Clive Gamble and Martin Porr (London: Routledge, 2005), 116, 120.

75. Brantingham et al., *Early Upper Paleolithic,* 78. The Neanderthal-modern human split is thought to date from 550,000–690,000 years ago (Willoughby, *Evolution of Modern Humans,* 148).

76. This is the view of Brantingham et al., *Early Upper Paleolithic,* 245; McBrearty and Brooks, "The Revolution That Wasn't," 529, 531–32; and Sterelny, *Thought in a Hostile World,* 115.

77. Radiocarbon dates for the three oldest figures tested at Chauvet are: 32,410 (±720), 30,940 (±610), and 30,340 (±570). Paul G. Bahn, "New Developments in Pleistocene Art 1995–1999," in *Rock Art Studies, News of the World* 2, ed. Paul G. Bahn and Angelo Fossati (Oxford: Oxbow Books, 2003). On these paintings generally, see Jean Clottes et al., *Chauvet Cave: The Art of Earliest Times,* trans. Paul G. Bahn (Salt Lake City: University of Utah Press, 2003). In carving, an important early example is the Gravettian female head in ivory from Brassempouy, 24,000–31,000 years old.

78. On African cave painting, see R. Townley Johnson, *Major Rock Paintings in Southern Africa,* ed. Tim Maggs (Bloomington: Indiana University Press, 1979); and McBrearty and Brooks, "The Revolution That Wasn't," 525–26.

79. See Richard Lewontin, *The Triple Helix: Gene, Organism, and Environment* (Cambridge: Harvard University Press, 2000); and John F. Olding-Smee, Kevin Laland, and Marcus Feldman, *Niche Construction* (Princeton: Princeton University Press, 2003).

80. Sterelny, *Thought in a Hostile World,* 150, 116. This "ratchet" effect of culture is important to Tomasello's argument in *Cultural Origins of Human Cognition,* to which I referred earlier in this chapter.

81. See Henry Petrosky, *Invention by Design* (Cambridge: Harvard University Press, 1996), chap. 7.

82. See the studies by George Basalla, *The Evolution of Technology* (Cambridge: Cambridge University Press, 1988); Andrew Feenberg, *Questioning Technology* (London: Routledge, 1999); Arnold Pacey, *The Culture of Technology* (Cambridge: MIT Press, 1983); Nathan Rosenberg, *Exploring the Black Box: Technology, Economics, and History* (Cambridge: Cambridge University Press, 1994); and Merritt Roe Smith and Leo Marx, eds., *Does Technology Drive History?* (Cambridge: MIT Press, 1994).

## 2. The Technical

1. I discuss the concept of artifact in *Knowledge and Civilization* (Boulder: Westview Press, 2004). Jorge Gracia, *A Theory of Textuality* (Albany: State University of New York Press, 1995), 44–51, offers a rigorous but inconclusive conceptual analysis. See also Michael Brian Schiffer, *The Material Life of Human Beings: Artifact, Behavior, and Communication* (London: Routledge, 1999); Randall R. Dipert, *Artifacts, Art Works, and Agency* (Philadelphia: Temple University Press, 1993); and the work of the "Dual Nature of Technical Artifacts" research group, collected in thematic issues of *Research in Philosophy and Technology* 20 (2000); *Techne* 6 (2002); and *Studies in the History and Philosophy of Science* 37 (2006).

2. On this theory of actions and events, see G. E. M. Anscombe, *Intention,* 2d ed. (Oxford: Blackwell, 1963); and Donald Davidson, *Essays on Actions and Events* (Oxford: Oxford University Press, 1980).

3. I draw from J. R. McNeill, *Something New under the Sun: An Environmental History of the Twentieth-Century World* (New York: W. W. Norton, 2000), 111–13; and Kent Peacock, "The Ozone Surprise," in *Living with the Earth,* ed. Kent Peacock (Toronto: Harcourt Brace, 1996). For a wide-ranging description of technological counterproductivity, see Edward Tenner, *Why Things Bite Back: Technology and the Revenge of Unintended Consequences* (New York: Vintage, 1997).

4. Schiffer, *Material Life,* 12. Gracia also considers side-effects and by-products of artifacts to be artifacts. Gracia, *Theory of Textuality,* 44–51.

5. For more, see my "The Abyss of Contingency: Contingency and Purposiveness in Darwin and Kant," *History of Philosophy Quarterly* 20 (2003): 373–91.

6. See Jack Goody, *The Logic of Writing and the Organization of Society* (Cambridge: Cambridge University Press, 1986).

7. This argument is obviously based on the work of Bruno Latour. On nature as an outcome of purification processes, see *We Have Never Been Modern,* trans. Catherine Porter (Cambridge: Harvard University Press, 1993); on centers of scientific calculation, *Science in Action* (Cambridge: Harvard University Press, 1987); on the ontology of the laboratory, "On the Partial Existence of Existing and Nonexisting Objects," in *Biographies of Scientific Objects,* ed. Lorraine Daston (Chicago: University of Chicago Press, 2000); and on inhuman claims to inhumanity, *Politics of Nature: How to Bring the Sciences into Democracy,* trans. Catherine Porter (Cambridge: Harvard University Press, 2004).

8. Friedrich Nietzsche, *The Gay Science,* trans. Walter Kaufmann (New York: Vintage, 1974), 57.

9. Aristotle, *De Partibus Animalium,* 640a, 645b; also 687a, "Hands are a tool"; in *The Basic Works of Aristotle,* ed. Richard McKeon (New York: Random House, 1941). There is a fascinating contrast drawn between the Greek model of fixing one's eyes on a form and ancient Chinese ideas about artisanal efficacy in François Jullien, *A Treatise on Efficacy: Between Western and Chinese Thinking,* trans. Janet Lloyd (Honolulu: University of Hawaii Press, 2004), chap. 1.

10. Plato, *Gorgias* 503e; *Timaeus* 28a–b; in *Complete Works,* ed. John M. Cooper (Indianapolis: Hackett, 1997); and David Roochnik, *Of Art and Wisdom: Plato's Understanding of Techne* (University Park: Pennsylvania State University Press, 1996), 206.

11. Aristotle, *Nicomachean Ethics* 1140a; *Metaphysics* 1032a; *De Partibus Animalium* 640a, 639b. Aristotle says that a man of experience can succeed better than one who has "theory without experience," though he adds that "we think *knowledge* and *understanding* belong to art rather than experience, and we suppose artists to be wiser than men of experience . . . because the former know the cause but the latter do not." From which he concludes that "the theoretical kinds of knowledge [are] more of the nature of wisdom than the productive." *Metaphysics* 981a–982a.

12. Thomas Aquinas, *Summa Theologica* I.a II.ae. Q.57 art. 3; *Introduction to St. Thomas Aquinas,* ed. Anton C. Pegis (New York: Random House, 1948), 571. Bonaventure, *Retracing the Arts to Theology, or Sacred Theology, the Mistress among the Sciences,* 12; in *Philosophy in the Middle Ages,* ed. Arthur Hyman and James J. Walsh, 2d ed. (Indianapolis: Hackett, 1973), 465. Thomas Aquinas adds: "The good of these things depends, not on the disposition of the man's appetite, but on the goodness of the work done. For a craftsman as such is commendable, not for the will with which he does a work, but for the quality of the work."

13. Auguste Comte, "Plan of the Scientific Operations Necessary for Reorganizing Society" (1822), in *Auguste Comte and Positivism: The Essential Writings,* ed. Gertrud Lenzer (New York: Harper & Row, 1975), 21.

14. Karl Marx, *Capital,* ed. Fredrick Engels, trans. Samuel Moore and Edward Aveling (Moscow: Progress Publishers, 1977), vol. 1, chap. 7, sec. 1, p. 174.

15. R. G. Collingwood, *Principles of Art* (Oxford: Oxford University Press, 1938), 15–16.

16. Ibid., 133.

17. On Collingwood, Ernst Cassirer, *An Essay on Man* (New Haven: Yale University Press, 1944), 4. On Aristotle, Joseph Dunn, *Back to the Rough Ground: Practical Judgment and the Lure of Technique* (Notre Dame: University of Notre Dame Press, 1997), 285.

18. Didier Maleuvre, *Museum Memories: History, Technology, Art* (Stanford: Stanford University Press, 1999), 64.

19. K. P. Oakley, "Skill as a Human Possession," in *A History of Technology,* vol. 1, ed. Charles Singer, E. J. Holmyard, and A. R. Hall (Oxford: Oxford University Press, 1954), 27. Kathy D. Schick and Nicholas Toth, *Making Silent Stones Speak: Human Evolution and the Dawn of Technology* (New York: Simon & Schuster, 1993), 231. Jacques Pelegrin, "A Framework for Analyzing Prehistoric Stone Tool Manufacture," in *The Use of Tools by Human and Nonhuman Primates,* ed. Arlette Berthelet and Jean Chavaillon (Oxford: Clarendon Press, 1993), 303. For mental template talk in archaeology, see François Bordes, "Physical Evolution and Technological Evolution in Man," *World Archaeology* 3 (1971): 1–5; and *The Ancient Mind: Elements of Cognitive Archaeology,* ed. C. Renfrew and E. B. W. Zubrow (Cambridge: Cambridge University Press, 1994), 154.

20. I draw from Charles Keller and Janet D. Keller, *Cognition and Tool Use* (Cambridge: Cambridge

University Press, 1996), 169; V. A. Howard, *Artistry: The Work of Artists* (Indianapolis: Hackett, 1982), 52, 130; and Christopher Baber, *Cognition and Tool Use* (London: Taylor and Francis, 2003), 43, 50.

21. Aristotle, *Politics* 1258b.

22. François Sigaut, cited in Tim Ingold, *The Perception of the Environment* (London: Routledge, 2000), 332.

23. David Pye, *The Nature and Aesthetics of Design* (Bethel, Conn.: Cambium Press, 1978), 14 (my emphasis).

24. Jürgen Habermas, *Knowledge and Human Interests,* trans. Jeremy Shapiro (Boston: Beacon Press, 1971), 192–93; and Jean-François Lyotard, *The Postmodern Condition: A Report on Knowledge,* trans. Geoff Bennington and Brian Massumi (Minneapolis: University of Minnesota Press, 1984), 44.

25. Edmund Leach, cited in Ingold, *Perception of the Environment,* 317.

26. Marcia-Anne Dobres, *Technology and Social Agency* (Malden, Mass.: Blackwell, 2000), 92–93.

27. Andrew Feenberg, *Questioning Technology* (London: Routledge, 1999), 180, 79.

28. Pierre Lemonnier, *Elements for an Anthropology of Technology* (Ann Arbor: Museum of Anthropology, University of Michigan, 1992), 53, 57 (my emphasis).

29. Ibid., 64, 51, 114.

30. J. E. Gordon, *Structures* (London: Penguin, 1978), 369.

31. Jane Goodall, *In the Shadow of Man* (London: Collins, 1971), 43. Nancy Makepeace Tanner, "Becoming Human," in *What Is an Animal?* ed. Tim Ingold (London: Unwin Hyman, 1988), 128. Jonathan Marks, *What It Means to Be 98% Chimpanzee* (Berkeley: University of California Press, 2003), 183.

32. Here are some definitions from the literature on animal tool use:

1. "[Tools are] specific combinations of different objects."
2. "A tool is some external object, used to achieve some end."
3. "Tool-use occurs because extraneous, extra-corporeal equipment is applied to the environment to extend the user's efficiency."
4. "[Tool use is] the external deployment of an unattached environmental object to alter more efficiently the form, position, or condition of another object."
5. "Tool-using is an act of improvisation in which a naturally occurring object is utilized for an immediate purpose, and discarded. . . . [This may include] adapting a naturally occurring object by simple means to improve its performance."

Sources: (1) Barbara Fruth and Gottfried Hohmann, in *Chimpanzee Cultures,* ed. R. W. Wrangham, W. C. McGrew, F. de Waal, and P. Heltne (Cambridge: Harvard University Press, 1994), 109; (2) Schick and Toth, *Making Silent Stones Speak,* 48; (3) Tim Megarry, *Society in Prehistory: The Origins of Human Culture* (New York: New York University Press, 1995), 155; (4) B. B. Beck, *Animal Tool Behavior* (New York: Garland Press, 1980), 10; (5) John Napier, *Hands,* rev. ed. (Princeton: Princeton University Press, 1993), 100–101. On the limitations of such definitions see my earlier critique of chimpanzee tools in *Knowledge and Civilization* (Boulder: Westview Press, 2004), chap. 6.

33. The ape/hominid divergence is now thought to be prior to 6 million years ago, probably between 7 and 9 million years. See B. Senut et al., in *The Human Evolution Source Book,* ed. Russell L. Ciochon and John G. Fleagle, 2d ed. (Upper Saddle River, N.J.: Pearson Prentice Hall, 2006). That means there is an interval of 4 to 6 million years between our last common ancestor with a chimpanzee and the first stone tools.

34. Citations from Schick and Toth, *Making Silent Stones Speak,* 58; Richard Wrangham, cited in Marks, *98% Chimpanzee,* 173; Crickette Sanz, Dave Morgan, and Steve Gulick, "New Insights into Chimpanzees, Tools, and Termites from the Congo Basin," *American Naturalist* 164 (2004): 567; and W. C. McGrew, *Chimpanzee Material Culture* (Cambridge: Cambridge University Press, 1992), 202, 230. For a skeptical view of these claims, see Adriaan Kortlandt, "The Use of Stone Tools by Wild-Living Chimpanzees and Earliest Hominids," *Journal of Human Evolution* 15 (1986): 77–132.

35. Wrangham et al., *Chimpanzee Cultures,* 2, 11, 22, 30, 33. Other skeptics of chimpanzee tools include Steven Mithen, *The Prehistory of the Mind* (London: Thames and Hudson, 1996), chap. 5, and "Mind, Brain, and Material Culture," in *Evolution and the Human Mind,* ed. Peter Carruthers and Andrew Chamberlain (Cambridge: Cambridge University Press, 2000); and Raymond Tallis, *The Hand: A Philosophical Inquiry into Human Being* (Edinburgh: University of Edinburgh Press, 2003).

36. Ernst Mayr, *What Evolution Is* (New York: Basic Books, 2001), 25–27.

37. Some primatologists use a "referent model" for human-chimpanzee comparison: tools are not true

homologies between humans and chimpanzees but chimpanzee tool use *is like* that of an unknown ancestor species that *is* homologous with humans in tool use. In other words, chimpanzee tools are a hypothetical analogy to an unknown homology. Behavioral diversity is more widespread among primates than any other mammal. All species are highly flexible in behavior, with little that is truly typical. That must raise doubt about the viability of any merely analogous comparison between humans and chimpanzees.

38. See Goodall, *Shadow of Man,* 226–27; and *The Chimpanzees of Gombe* (Cambridge: Harvard University Press, 1986).

39. On Kanzi, I draw from Wrangham et al., *Chimpanzee Cultures,* 367; and Schick and Toth, *Making Silent Stones Speak,* 139. I do not understand how McGrew can say that "everything attributed to hominids at the level of Oldowan culture at Olduvai or Koobi Fora could have been done by pongids." William McGrew, "The Intelligent Use of Tools," in *Tools, Language, and Cognition in Human Evolution,* ed. Kathleen R. Gibson and Tim Ingold (Cambridge: Cambridge University Press, 1993), 166.

40. On gorilla hands, Napier, *Hands,* 58, 76. Gorillas are notably handy, especially in dealing with "embedded" (difficult to reach) food. See Alison Jolly, *Lucy's Legacy: Sex and Intelligence in Human Evolution* (Cambridge: Harvard University Press, 1999), 201–2.

41. Wrangham et al., *Chimpanzee Culture,* 315. See also R. Wrangham and D. Pilbeam, "African Apes as Time Machines," in Ciochon and Fleagle, *Human Evolution Source Book.* They argue that neither bonobos nor chimpanzees offer convincing homologies to humans.

42. Frans B. M. de Waal, ed., *Tree of Origin* (Cambridge: Harvard University Press, 2001), 137. On the dating of fire, see Mike Barbetti, "Traces of Fire in the Archaeological Record Before One Million Years Ago?" *Journal of Human Evolution* 15 (1986): 771–81; and Peter Bogucki, *The Origins of Human Society* (Oxford: Blackwell, 1999), 54.

43. George Basalla, *The Evolution of Technology* (Cambridge: Cambridge University Press, 1988), 13; and Laura Westra, *Living in Integrity: A Global Ethic to Restore a Fragmented World* (Lanham: Rowman and Littlefield, 1998), 138.

44. On adaptations specifically for stone tool use, see Mary Marzke, "Evolutionary Development of the Human Thumb," *Hand Clinics* 8 (1) (1992): 1–8; and Wilson, *The Hand,* 132–34, 160–61.

45. See Peter Reynolds, "The Complementation Theory of Language and Tool Use," in *Tools, Language, and Cognition,* 412. The social character of technical action is a theme in the work of archaeologist Marcia-Anne Dobres. Besides her book *Technology and Social Agency,* to which I've already referred, see the edited work with Christopher R. Hoffman, *The Social Dynamics of Technology* (Washington, D.C.: Smithsonian Institution Press, 1999). For a demonstration of socio-technical interaction in modern technology, see Robert Pool, *Beyond Engineering* (New York: Oxford University Press, 1997), esp. chap. 1.

46. I draw from Michael Tomasello and Josep Call, *Primate Cognition* (Oxford: Oxford University Press, 1997), 288–89, 294, 296, 308, 310. There is a large literature on primate imitation, and practically all of it runs contrary to "monkey see, monkey do." It remains uncertain whether *any* nonhuman primate is capable of learning by imitation. For a summary of the evidence see Richard Byrne, *The Thinking Ape: Evolutionary Origins of Intelligence* (Oxford: Oxford University Press, 1995), chap. 6. On the variety of social learning, see Peter J. Richerson and Robert Boyd, *Not by Genes Alone: How Culture Transformed Human Evolution* (Chicago: University of Chicago Press, 2005), 104–9.

47. I draw from Kim Sterelny, *Thought in a Hostile World: The Evolution of Human Cognition* (Malden, Mass.: Blackwell, 2003), 55, 61, 63, 64, 144.

48. S. Semaw, "The World's Oldest Stone Artifacts," *Journal of Archaeological Science* 27 (2000): 1197–1214. The author places the Gona artifacts with Oldowan tools, and thinks they were more probably the work of an early *Homo* species, rather than of an australopithecine.

49. On these claims about Oldowan tools, see Oakley, "Skill"; Mithen, *Prehistory of the Mind,* 96; and Marcello Piperno, "The Origin of Tool Use and the Evolution of Social Space in Paleolithic Times," in *Use of Tools by Primates,* ed. Berthelet and Chavaillon, 254–66.

50. Mithen, *Prehistory of the Mind,* 75, 78.

51. Sanz et al., "Chimpanzees, Tools, and Termites." A novelty of this research is the use of sound-activated digital cameras at termite nest sites to record the chimpanzees feeding. Clips from the video footage are available at http://www.journals.uchicago.edu/AN/journal/issues/v164n5/40471/40471.html (accessed 1 December 2007).

52. David Premack, *Gavagai! The Future History of the Animal Language Controversy* (Cambridge: MIT Press, 1986), 152. See also Premack, "Pedagogy and Aesthetics as Sources of Culture," in *Handbook of Cognitive Neuroscience,* ed. Michael Gazzaniga (New York: Plenum Press, 1984), 15–35. Christophe Boesch claims to have twice observed a mother chimpanzee helping her infant learn nut-cracking. Despite observing only two momentary episodes in more than sixty-eight hours of field study, and with nothing comparable in the scientific literature on chimpanzee behavior, he draws the unqualified conclusion that chimpanzees "observe their infants' behavior and intervene in it," that they both "compare their offspring's behavior to their own conception of how it should be performed," and "anticipate the possible effects of their actions on those of their offspring." "Aspects of Transmission of Tool-Use in Wild Chimpanzees," in Gibson and Ingold, *Tools, Language, and Cognition,* 174, 178. For a spectrum of expert opinion, all skeptical, see Jolly, *Lucy's Legacy,* 301; Michael Tomasello, *The Cultural Origins of Human Cognition* (Cambridge: Harvard University Press, 1999), 33–34; Tomasello and Call, *Primate Cognition,* 306–8; and Byrne, *Thinking Ape,* 140–44.

53. Not all *erectus* populations made the teardrop form. The so-called Movius Line, running through eastern Europe, the Anatolian peninsula, and northern India, roughly demarcates *erectus* populations that did (south and west) and did not (north and east). Schick and Toth, *Making Silent Stones Speak,* 276 (I also draw from page 240).

54. On caches of unused Acheulian handaxes, see Richard G. Klein and Blake Edgar, *The Dawn of Human Culture* (New York: Wiley, 2002), 106–7. I reproduce a photograph of the Furze Platt artifact and discuss its significance in *Knowledge and Civilization.*

55. On aesthetic standards, especially "their nature as essentially fluid and re-integratable, rather than closely controlling and pre-programmed," see Michael Carrithers, *Why Humans Have Cultures* (Oxford: Oxford University Press, 1992), 64–66.

56. Manipulated facilitation is different from simple manipulation. When gorillas use their hands to manipulate around a pod's spiny barbs and expose the pith inside nothing is made to facilitate. Instead, the manipulation, the dexterity, *is* the facilitation, facilitating eating otherwise inedible foods.

57. Tomasello and Call, *Primate Cognition,* 58.

58. See Daniel Dennett, *Elbow Room: The Varieties of Free Will Worth Wanting* (Cambridge: MIT Press, 1984), 10–13; and Keith E. Stanovich, *The Robot's Rebellion: Finding Meaning in the Age of Darwin* (Chicago: University of Chicago Press, 2004), 74–75.

59. Rudolf Arnheim, *Visual Thinking* (Berkeley: University of California Press, 1969), 89–90.

60. See Daniel C. Dennett, *The Intentional Stance* (Cambridge: MIT Press, 1987).

61. On black boxes, see Latour, *Science in Action,* and *Pandora's Hope: Essays on the Reality of Science Studies* (Cambridge: Harvard University Press, 1999). "Real objects are always parts of institutions, trembling in their mixed status as mediators, mobilizing faraway lands and people, ready to become people or things, not knowing if they are composed of one or of many, of a black box counting for one or of a labyrinth concealing multitudes." "On Technical Mediation," *Common Knowledge* 3 (2) (1994): 46.

62. Latour, *Science in Action,* 138–39.

63. Factual claims in this paragraph draw from Steven Stanley, *Children of the Ice Age* (New York: W. H. Freeman, 1998), 163–67, 195–98, 234; Richard G. Klein, *The Human Career: Human Biological and Cultural Origins* (Chicago: University of Chicago Press, 1989), 131, 133, 158, 403; Richard Leakey and Roger Lewin, *Origins Reconsidered* (New York: Anchor Books, 1992), 112; Schick and Toth, *Making Silent Stones Speak,* 227; Klein and Edgar, *Dawn of Human Culture,* 82–85; Merlin Donald, *Origins of the Modern Mind* (Cambridge: Harvard University Press, 1991), 111; Clive Gamble, *Timewalkers: The Prehistory of Global Colonization* (Cambridge: Harvard University Press, 1994), 70; and Semaw, "World's Oldest Stone Artifacts." The tools at Hadar, another Ethiopian site, may be 3 million years old. Some authorities think Acheulian tools originate with *H. ergaster,* probably the last common ancestor between *sapiens* and *erectus,* which is no longer reckoned in the *sapiens* genealogy.

64. I draw from Klein, *Human Career,* 169; Schick and Toth, *Making Silent Stones Speak,* 125–26, 127, 221, 139, 142; Leakey and Lewin, *Origins Reconsidered,* 254; Mithen, *Prehistory of the Mind,* 96; Megarry, *Society in Prehistory,* 159, 185; Jean Kithahara-Frisch, "The Origin of Secondary Tools," in *Use of Tools by Primates,* ed. Berthelet and Chavaillon, 239–48; Tallis, *The Hand,* 229; and Clive Gamble and Sabine Gaudzinski, "Bones of Powerful Individuals," in *The Hominid Individual in Context,* ed. Clive Gamble and Martin Porr (London: Routledge, 2005). Average cranial capacity for *A. africanus* is 450 ml. Average for the

Olduvai *Homo* is 650 ml, with higher figures for other early *Homo* finds. The former *A. afarensis* has been reclassified as *Preanthropus afarensis,* from 3.2 million years ago.

65. Schick and Toth, *Making Silent Stones Speak,* 133.

66. On Oldowan tools and chimpanzee proto-tools, Dobres, *Technology and Social Agency,* 228.

67. I drawn on Melvin Konner, *The Tangled Wing,* 2d ed. (New York: Henry Holt, 2002), 93, 198; and Lionel Tiger and Robin Fox, *The Imperial Animal* (New Brunswick: Transaction, 1998), 208–11.

68. Ivan Illich, *Tools for Conviviality* (New York: Harper & Row, 1973), 22. On Vygotski, see Baber, *Cognition and Tool Use,* 104, 106; and on cognitive artifacts, ibid., chap. 9. Another intangible tool is a software tool or digital artifact, shaped by software operations, composed of data assemblies, lacking physical substance, yet a thing with an appearance, spatiality, structure, and history. See Malcolm McCullough, *Abstracting Craft: The Practiced Digital Hand* (Cambridge: MIT Press, 1996). A software tool also satisfies my two conditions on tools—economic artifactuality and functionless functionality.

69. See Jean Bottéro, Clarisse Herrenschmidt, and Jean-Pierre Vernant, *Ancestor of the West: Writing, Reasoning, and Religion in Mesopotamia, Elam, and Greece,* trans. Teresa Lavender Fagan (Chicago: University of Chicago Press, 2000).

70. The idea of the "type" of any historical alphabet may be a mistake. As historian of images James Elkins argues, there is "no foundation, no 'zero-degree' script that is entirely unornamented, and therefore—it is important to state this directly—there is no hope of ever defining calligraphy"—namely, by invidious comparison to a type. *The Domain of Images* (Ithaca: Cornell University Press, 1999), 96.

71. Jack Weatherford, *The History of Money* (New York: Three Rivers, 1997), 233. I also draw from pages 27, 30, 75, 78, 124, 126, 130, 179, 180. Paper money was used in China in the first and second centuries C.E.

72. See Jason Robert, *Embryology, Epigenesis, and Evolution: Taking Development Seriously* (Cambridge: Cambridge University Press, 2004).

73. Charles Darwin, *The Descent of Man,* in *The Origin of Species and The Descent of Man* (New York: Modern Library, 1936), 91.

74. Tim Ingold, "Art and Technology," in *Anthropological Perspectives on Technology,* ed. Michael Brian Schiffer (Albuquerque: University of New Mexico Press, 2001), 27, 28. On *bilums* and the women who make them, see M. A. MacKenzie, *Androgynous Objects: String Bags and Gender in Central New Guinea* (Char, Switzerland: Harwood Academic, 1991).

75. In Bruno Latour's terms, "Skills emerge in the zone of transaction, they are properties of the assembly that circulate or are redistributed among human and nonhuman technicians." "Technical Mediation," 45. Ingold makes similar observations in *Perception of the Environment,* 321, 353, 360, 366; as does Latour's colleague M. Callon: "No description of skills is possible unless the networks of humans, texts, and machines within which they are expressed and put to work are reconstituted." "Techno-Economic Networks and Irreversibility," in *A Sociology of Monsters: Essays on Power, Technology, and Domination,* ed. John Law (London: Routledge, 1991), 138.

76. See Janet L. Starkes and Fran Allard, eds., *Cognitive Issues in Motor Expertise* (Amsterdam: North-Holland, 1993), 19–21, 328–29, 341–42. Rudolf Arnheim is cited from *Toward a Psychology of Art* (Berkeley: University of California Press, 1966), 317.

77. I draw from Dennis H. Holding, ed., *Human Skills* (Chichester: Wiley, 1981), 53; Jan P. Piek, ed., *Motor Behavior and Human Skill* (Champaign, Ill.: Human Kinetics, 1998), 143; Andy Clark, *Being There* (Cambridge: MIT Press, 1997), 44; Christine L. MacKenzie and Thea Iberall, *The Grasping Hand* (Amsterdam: North-Holland, 1994); 344; Nicolai Bernstein, *Dexterity and Its Development,* ed. M. Latash and M. T. Turvey (Mahwah: Lawrence Erlbaum, 1996); and Ingold, "Art and Technology," 21.

78. Paul Ricoeur, *Freedom and Nature: The Voluntary and the Involuntary,* trans. Erazim V. Kohák (Evanston: Northwestern University Press, 1966), 289.

## 3. The Aesthetic

1. D. E. Berlyne, *Aesthetics and Psychobiology* (New York: Appleton-Century-Crofts, 1971), 176, 181. When speaking of *feeling* in connection with the aesthetic, I follow neurologist Antonio Damasio's distinction between emotion and feelings. Feelings are body feelings, kinesthetic self-perceptions (ideas of the

body, Spinoza would have said). They are always pleasurable or painful, and shadow both emotional states and perception, as the body's first, felt response to stimuli. *Looking for Spinoza: Joy, Sorrow, and the Feeling Brain* (Orlando: Harcourt, 2003).

2. Sigmund Freud, *Three Essays on the Theory of Sexuality,* Pelican Freud Library, vol. 7 (Harmondsworth: Penguin, 1977), 69; and *Civilization and Its Discontents,* Pelican Freud Library, vol. 12 (Harmondsworth: Penguin, 1985), 271.

3. Eckart Voland, "Aesthetic Preferences in the World of Artifacts," in *Evolutionary Aesthetics,* ed. Eckart Voland and Karl Grammar (Berlin: Springer, 2003), 253; and Randy Thornhill, "Darwinian Aesthetics," ibid., 21, 9. There is reportedly some perceptual preference in mammals and birds; see Irenäus Eibl-Eibesfeldt, "The Biological Foundation of Aesthetics," in *Beauty and the Brain: Biological Aspects of Aesthetics,* ed. Ingo Rentschler, Barbara Herzberger, and David Epstein (Basel: Birkhäuser Verlag, 1988).

4. The similarity of response to natural scenes outweighs differences across individuals, groups, and cultures. Roger S. Ulrich, "Biophilia, Biophobia, and Natural Landscapes," in *The Biophilia Hypothesis,* ed. Stephen R. Kellert and Edward O. Wilson (Washington, D.C.: Island Press, 1993), 93. See also Bernhart Ruso et al., "Human Habitat Preference," in Voland and Grammar*, Evolutionary Aesthetics;* and Gordon H. Orians and Judith H. Heerwagen, "Evolved Responses to Landscapes," in *The Adapted Mind: Evolutionary Psychology and the Generation of Culture,* ed. Jerome H. Barkow, Leda Cosmides, and John Tooby (Oxford: Oxford University Press, 1992).

5. See Reginald G. Golledge, "Human Wayfinding and Cognitive Maps," in *Colonization of Unfamiliar Landscapes: The Archaeology of Adaptation,* ed. Marcy Rockman and James Steele (London: Routledge, 2003).

6. See Voland, "Aesthetic Preferences."

7. See Richard G. Coss, "Role of Evolved Perceptual Biases in Art and Design"; and Steven Mithen, "Handaxes: The First Aesthetic Artifacts," both in *Evolutionary Aesthetics*.

8. Voland, "Aesthetic Preferences," 246. For the evidence of cross-cultural beauty, see Melvin Konner, *The Tangled Wing,* 2d ed. (New York: Henry Holt, 2002), 270; G. F. Miller, *The Mating Mind* (New York: Doubleday, 2000), 281; and N. Etcoff, *Survival of the Prettiest* (New York: Doubleday, 1999).

9. Moshe Barasch, *Modern Theories of Art,* vol. 2: *Impressionism to Kandinsky* (New York: New York University Press, 1998), 32, 82, 280.

10. Leo Tolstoy, *What Is Art?* trans. Aylmer Maude (Indianapolis: Hackett, 1996). Variations on Tolstoy's approach are found in the "expressive" theories of Benedetto Croce and R. G. Collingwood. See Gordon Graham, "Expressivism," in *The Routledge Companion to Aesthetics,* ed. Berys Gaut and Dominic McIvers Lopes (London: Routledge, 2001).

11. Johann G. Herder, *Ideas for a Philosophy of the History of Mankind* (1784–91), in *J. G. Herder on Social and Political Culture,* ed. F. M. Bernard (Cambridge: Cambridge University Press, 1969), 300.

12. Barasch, *Modern Theories of Art,* 279–80.

13. I'm thinking of visual art, though the point holds, mutatis mutandis, for poetry and music. In the theory of Peter Kivy, music expresses emotions by promoting the recognition of similarities with emotional experience. Sad music is significantly like what sadness bodily feels like. Yet structural isomorphism alone is inadequate to imbue perceptions with expressiveness. Only some of the isomorphisms are attended to and (for a reason Kivy can't say) *animated.* "For whatever reason, [we] animate our perceptions, and cannot but see expressiveness in them." *The Corded Shell: Reflections on Musical Expression* (Princeton: Princeton University Press, 1980), 62. Gestalt theory can do a little better. Perception is an abstracting, comparing, generalizing, difference-detecting, tension-sensing organ, acutely sensitive to the way things tend to *change.* The isomorphisms we attend to are those we learn from evolved environmental perception.

14. Rudolf Arnheim, *Art and Visual Perception,* rev. ed. (Berkeley: University of California Press, 1974), 97.

15. Ibid., 423, 455. "Every aspect of our visual system is designed to go beyond the physical stimulus presented to the eye . . . [and] construct visual reality in such a way as to improve our adaptation to our environment." James T. Enns, *The Thinking Eye, the Seeing Brain* (New York: Norton, 2004), 350.

16. Rudolf Arnheim, *Toward a Psychology of Art* (Berkeley: University of California Press, 1966), 208.

17. E. H. Gombrich, *Art and Illusion: A Study in the Psychology of Pictorial Representation,* 2d ed. (Princeton: Princeton University Press, 1961), 345. See also Patrick Maynard, *Drawing Distinctions: The Varieties of Graphic Expression* (Ithaca: Cornell University Press, 2005), esp. 97, 214–15.

18. Cue validity (shaggy hump predicts bison, snout horns predict rhino, and so on) is characteristic of Paleolithic painting and carving; see John Halverson, "Paleolithic Art and Cognition," *Journal of Psychology* 126 (1992): 231.

19. Paul Souriau, *The Aesthetics of Movement,* trans. Manon Souriau (Amherst: University of Massachusetts Press, 1983), 141. Wassily Kandinsky, *On the Spiritual in Art,* cited in Barasch, *Modern Theories of Art,* 350. Paul Bonnard, *Drawings by Bonnard* (London: Arts Council of Great Britain, 1984), 5–6. See also Arnheim, *Visual Perception,* 448. Kandinsky found colors no less expressive. Squeeze a paint tube and out come "strange beings . . . exultant, solemn, brooding, dreamy, self-absorbed, deeply serious, with roguish exuberance, with a sign of release, with a deep sound of mourning, with defiant power and resistance, with submissive suppleness and devotion, with obstinate self-control, with sensitive, precarious balance, living an independent life of their own." *Reminiscences,* in *Complete Writings on Art,* ed. Kenneth C. Lindsay and Peter Vergo (Boston: G. K. Hall, 1982), 371–72.

20. David Rosand, *Drawing Acts: Studies in Graphic Expression and Representation* (Cambridge: Cambridge University Press, 2002), 12–13.

21. Michael Fried, "Art and Objecthood" (1967), cited in Marvin Carlson, *Performance,* 2d ed. (New York: Routledge, 2004), 139.

22. On the aesthetics of plans and diagrams, see Rudolf Arnheim, *Visual Thinking,* chap. 16; and James Elkins, *The Domain of Images* (Ithaca: Cornell University Press, 1999).

23. Michelangelo is cited from Giorgio Vasari, *Lives of the Artists* (1550); Francisco de Hollanda, *Four Dialogues on Painting* (1548); and Giovan Paolo Lomazzo, *Trattato della pittura* (1584), all in David Summers, *Michelangelo and the Language of Art* (Princeton: Princeton University Press, 1981), 257–58, 370, 72. On *disegno* see also Niklas Luhmann, *Art as a Social System,* trans. Eva M. Knodt (Stanford: Stanford University Press, 2000), 263–64; and Rosand, *Drawing Acts,* chap. 2.

24. Immanuel Kant, *Critique of Judgment,* trans. Werner S. Pluhar (Indianapolis: Hackett, 1987), 14.

25. "The plan is the generator." "The plan is what determines everything." "The whole structure rises from its base and is developed in accordance with a rule which is written on the ground in the plan." "Without plan there can be neither grandeur of aim and expression, nor rhythm, nor mass, nor coherence." Le Corbusier, *Toward a New Architecture,* trans. Frederick Etchells (New York: Payson and Clarke, 1929), 47, 48.

26. Plato, *Philebus* 64e; *Timaeus* 87c. Aristotle, *Poetics* 1450b. On the classical theory of beauty and its vicissitudes, see Wladyslaw Tartarkiewicz, *A History of Six Ideas: An Essay in Aesthetics* (The Hague: Martinus Nijhoff, 1980), chap. 4.

27. On the lack of imaginative coherence in smells and tastes, see Karl Aschenbrenner, *The Concept of Coherence in Art* (Dordrecht: D. Reidel, 1985), 76–85. On the aesthetics of smell, Paul Jellinek, *The Practice of Modern Perfumery* (London: Leonard Hill, 1959). On tastes, Jean Anselme Brillat-Savarin, *The Physiology of Taste, or Meditation on Transcendental Gastronomy,* trans. M. F. K. Fisher (1949; New York: Counterpoint, 2000); and on the Chinese aesthetic of "discerning flavors," François Jullien, *In Praise of Blandness: Proceeding from Chinese Thought and Aesthetics,* trans. Paula M. Varsano (New York: Zone Books, 2004), 104–5.

28. See Crispin Sartwell, *Six Names for Beauty* (New York: Routledge, 2004).

29. Alexander Nehamas disparages works that merely *look* beautiful—good looking, but without the "promise of happiness" that he thinks is essential to beauty. My impression, however, is that what he calls "beauty" is not the thing itself; it is one man's beauty, one way of describing one thing that beauty can be, if only for people like him. Before a work can promise happiness it has to have compulsive perceptual presence. The art is in that, and so too the beauty. Some of these works may "promise happiness," but I cannot believe that this lofty response to artifice is the "essence" of beautiful art. See Alexander Nehamas, *Only a Promise of Happiness: the Place of Beauty in a World of Art* (Princeton: Princeton University Press, 2007).

30. Plotinus, *The Enneads,* trans. Stephen MacKenna, ed. John Dillon (Harmondsworth: Penguin, 1991), I.6.1.

31. On the work with raw pigment by Anish Kapoor, see Philip Ball, *Bright Earth: Art and the Invention of Color* (Chicago: University of Chicago Press, 2001). On Wolfgang Laib, see Klaus Ottman, *Wolfgang Laib: A Retrospective* (New York: American Federation of Arts & Hatje Cantz, 2000).

32. Bernard Bosanquet, *Three Lectures on Aesthetic,* ed. Ralph Ross (Indianapolis: Bobbs-Merrill, 1963), 54.

33. G. W. F. Hegel, *Aesthetics: Lectures on Fine Art,* vol. 1, trans. T. M. Knox (Oxford: Clarendon Press, 1975), 527.

34. Ibid., 205, 222. "Romantic" art, for Hegel, begins in the later Middle Ages.

35. David Pye, *The Nature and Aesthetics of Design* (Bethel, Conn.: Cambium Press, 1978), 136. Constable cited in Matthew Kieran, *Revealing Art* (London: Routledge, 2005), 76.

36. Peter A. Carmichael, "The Sense of Ugliness," *Journal of Aesthetics and Art Criticism* 30 (1972): 495–98. See also Ruth Lorand, "Beauty and Its Opposites," *Journal of Aesthetics and Art Criticism* 52 (1994): 399–406; and Carolyn Korsmeyer, "Terrible Beauties," in *Contemporary Debates in Aesthetics and the Philosophy of Art,* ed. Matthew Kieran (Malden, Mass.: Blackwell, 2006). German philosophy after Hegel also produced some work on ugliness (*Hässlichkeit*), for instance Karl Rosenkrantz, *Aesthetik des Hässlichen* (1853).

37. The most Kant allows is that beauty is a *symbol* of morality. In *The Descent of Man,* Darwin writes, "The social instincts,—the prime principle of man's moral constitution—with the aid of active intellectual powers and the effects of habit, naturally lead to the golden rule, 'As ye would, that men should do to you, do ye to them likewise'; and this lies at the foundation of morality." *The Origin of Species and The Descent of Man* (New York: Modern Library, 1936), 495.

38. On photographs of atrocity, see Susan Sontag, *On Photography* (London: Allen Lane, 1977), 20; and Barbie Zelizer, *Remembering to Forget: Holocaust Memory through the Camera's Eye* (Chicago: University of Chicago Press, 1997).

39. On the aesthetics of nature, see Malcolm Budd, *The Aesthetic Appreciation of Nature* (Oxford: Clarendon Press, 2002).

## 4. Technology

1. All of these technological "advances" are subject to major caveat. Health: see Ivan Illich, *Limits to Medicine* (Harmondsworth: Penguin, 1990). Housework: see Ruth Schwartz Cowan, "Less Work for Mother?" in *Controlling Technology,* ed. Eric Katz, Andrew Light, and William Thompson, 2d ed. (Amherst, N.Y.: Prometheus Books, 2003). Agriculture: see James C. Scott, *Seeing Like a State* (New Haven: Yale University Press, 1998); and Vandana Shiva, *Monocultures of the Mind: Perspectives on Biodiversity and Biotechnology* (London: Zed Books, 1993). Democracy: see Herbert I. Schiller, *Culture, Inc.: The Corporate Takeover of Public Expression* (Oxford: Oxford University Press, 1989); and Langdon Winner, "Citizen Virtues in a Technological Order," in *Technology and the Politics of Knowledge,* ed. Andrew Feenberg and Alastair Hannah (Bloomington: Indiana University Press, 1995).

2. Carl Mitcham, cited in Albert Borgmann, *Technology and the Character of Contemporary Life* (Chicago: University of Chicago Press, 1984), 13; David Rothenberg, *Hand's End: Technology and the Limits of Nature* (Berkeley: University of California Press, 1993), 15, 29; Pierre Lemonnier, *Elements for an Anthropology of Technology* (Ann Arbor: Museum of Anthropology, University of Michigan, 1992), 1–2; and Robert McCormick Adams, *Paths of Fire: An Anthropologist's Inquiry into Western Technology* (Princeton: Princeton University Press, 1996), 6, 16. On the history of the word "technology," see Thomas P. Hughes, *Human-Built World: How to Think about Technology and Culture* (Chicago: University of Chicago Press, 2004), 2–5.

3. See for instance Lewis Mumford, *Technics and Civilization* (New York: Harcourt, Brace & World, 1934).

4. Franz Reuleaux, *Kinematics of Machinery,* trans. A. B. W. Kennedy (London, 1876), 35; cited in Abbott Payson Usher, *A History of Mechanical Inventions,* rev. ed. (Boston: Beacon, 1959), 117.

5. Usher, *Mechanical Inventions,* 119.

6. See Grant A. Whatmough, "Money, Machines, Energy, and Wealth," in *Living with the Earth,* ed. Kent A. Peacock (Toronto: Harcourt Brace, 1996). I have learned more from this profound essay than this sole reference suggests.

7. Peter N. Sterns, *The Industrial Revolution in World History* (Boulder: Westview Press, 1993), 58. Introducing the assembly line increased operation costs (136).

8. See for instance Hans Jonas, "Toward a Philosophy of Technology," in Katz et al., *Controlling Technology.*

9. John Lienhard, *The Engines of Our Ingenuity* (Oxford: Oxford University Press, 2000), 170.

10. Eugene Ferguson tells the story of Oliver Evans, a Delaware farm boy who claimed to have designed his automatic flour mill in his head: "The arrangement I so far completed [in my mind] before I began [to build] my mill that I have in my bed viewed the whole operation with much mental anxiety." *Engineering and the Mind's Eye* (Cambridge: MIT Press, 1992), 47.

11. William Ivins, cited in Ferguson, *Engineering and the Mind's Eye,* 76. The difficulty of communicating artisanal techniques in language is a theme of works on such topics from the beginning of print; for instance Cellini's treatise on goldsmithing (1568) and Bernard Palissy's treatise on glasswork (1580). See Pamela O. Long, *Openness, Secrecy, Authorship: Technical Arts and the Culture of Knowledge from Antiquity to the Renaissance* (Baltimore: Johns Hopkins University Press, 2001), chap. 7.

12. Ken Baynes and Francis Pugh, *The Art of the Engineer* (Guildford: Lutterworth Press, 1981), 13–15.

13. J. E. Gordon, *Structures* (London: Penguin, 1978), 369. I also draw from Baynes and Pugh, *Art of the Engineer,* 11, 31; Ferguson, *Engineering and the Mind's Eye,* 5, 9; Rudolf Arnheim, *Visual Thinking* (Berkeley: University of California Press, 1969), 129, 308; Bruno Latour, "Visualization and Cognition: Thinking with Eyes and Hands," *Knowledge and Society* 6 (1986): 22; and Brooke Hindle, *Emulation and Invention* (New York: New York University Press, 1981), 93, 133. Hindle discusses Robert Fulton and S. F. B. Morse, two inventors who were also artists. Indeed, Morse was the most prominent American artist of his day and the country's first professor of art (at NYU). Fulton, also a painter, was less accomplished.

14. Baynes and Pugh, *Art of the Engineer,* 34–35.

15. Ibid., 173, 177, 202.

16. I draw on David F. Noble, *The Religion of Technology* (New York: Penguin, 1999), 12, 15, 17, 18, 20. Erigena is commenting on Martianus Capella, *The Marriage of Philology and Mercury.* See also *The Didascalicon of Hugh of St. Victor,* trans. and ed. Jerome Taylor (New York: Columbia University Press, 1961); and Ivan Illich, *In the Vineyard of the Text: A Commentary on Hugh's "Didascalicon"* (Chicago: University of Chicago Press, 1993).

17. Noble, *Religion of Technology,* 22, 26, 48, 53, 83–86, 209–10, 214.

18. I. B. Cohen, *Benjamin Franklin's Science* (Cambridge: Harvard University Press, 1990), 29–30. Thomas Jefferson also declined to patent his moldboard.

19. I draw from Daniel Sarewitz, *Frontiers of Illusion: Science, Technology, and the Politics of Progress* (Philadelphia: Temple University Press, 1996), 130–31, 138–39; Ivan Illich, *Tools for Conviviality* (New York: Harper & Row, 1973), 33–34; Nathan Rosenberg, *Exploring the Black Box: Technology, Economics, and History* (Cambridge: Cambridge University Press, 1994), 20–21, 256; and Jack Wilson, "Intellectual Property Rights in Genetically Modified Agriculture," in *Genetically Modified Foods,* ed. Michael Ruse and David Castle (Amherst, N.Y.: Prometheus Books, 2002), 158–59.

20. David P. Billington, *The Tower and the Bridge: The New Art of Structural Engineering* (Princeton: Princeton University Press, 1983), 9.

21. Walter G. Vincenti, *What Engineers Know and How They Know It* (Baltimore: Johns Hopkins University Press, 1990), 166.

22. My discussion of the Britannia Bridge draws from Nathan Rosenberg and Walter G. Vincenti, *The Britannia Bridge: The Generation and Diffusion of Technological Knowledge* (Cambridge: MIT Press, 1978).

23. Rosenberg and Vincenti, *Britannia Bridge,* 67–68. Cast iron, sometimes called pig iron, is about 2.5 percent carbon as a product of blast-furnace smelting. It has a low melting point (2200° F), is readily cast in molds, and is strong in compression but weak in tension. Wrought iron has much less carbon (0.1 percent), a higher melting point (2700° F), is malleable (cast iron is not), and can be hammered or rolled into shape. It is strong in tension and compression, but did not became available in industrial quantity until the puddling process for removing carbon from pig iron, invented by Henry Cort (1784) and Joseph Hall (1839).

24. See Karl Popper, *The Logic of Scientific Discovery* (London: Hutchinson, 1948); and *Conjectures and Refutations,* 3d ed. (London: Routledge, 2002).

25. W. V. O. Quine, "Two Dogmas of Empiricism," in *From a Logical Point of View,* 2d ed. (New York: Harper & Row, 1961), 43, 44. "Engineering can show us much about scientific methodology." William C. Wimsatt, *Re-Engineering Philosophy for Limited Beings* (Cambridge: Harvard University Press, 2007), 316.

26. George Basalla, *The Evolution of Technology* (Cambridge: Cambridge University Press, 1988), 208–

9. I also draw from Edward W. Constant, "Communities and Hierarchies: Structure in the Practice of Science and Technology," in *The Nature of Technological Knowledge,* ed. Rachel Laudan (Dordrecht: D. Reidel, 1984), 28–29; Rachel Laudan, "Cognitive Change in Technology and Science," ibid., 98; Vincenti, *What Engineers Know,* 225; and Ferguson, *Engineering and the Mind's Eye,* 60, 63–64. On the importance of technological expertise and interactions among technologists (rather than scientific expertise) in engineering design, see Louis L. Bucciarelli, *Designing Engineers* (Cambridge: MIT Press, 1994).

27. Paul Forman, "Recent Science: Late-Modern and Postmodern," in *Science Bought and Sold: Essays in the Economics of Science,* ed. Philip Mirowski and Esther-Mirjam Sent (Chicago: University of Chicago Press, 2002), 116.

28. Sarewitz, *Frontiers of Illusion,* 37; and Rosenberg, *Exploring the Black Box,* 20–21.

29. Ian Hacking, *Representing and Intervening* (Cambridge: Cambridge University Press, 1983), 269–70. See also Michael Smithurst, "Do Successes of Technology Evidence the Truth of Theories?" in *Philosophy and Technology,* ed. Roger Fellows (Cambridge: Cambridge University Press, 1995); and Derek J. de Solla Price, "Notes toward a Philosophy of the Science/Technology Interaction," in Laudan, *Nature of Technological Knowledge.* The anecdote about Feynman comes from Paul Forman, "Recent Science: Late-Modern and Postmodern," in *Science Bought and Sold,* ed. Mirowski and Sent, 119.

30. Rosenberg, *Exploring the Black Box,* 256–58.

31. Ibid., 142–46. Dividing the scientific field into basic and applied was a political strategy of the Cold War and its military-technoscientific complex. See Mirowski and Sent, *Science Bought and Sold,* 22–23. An authoritative source for the idea in its Cold War setting was Vannevar Bush, wartime science advisor to President Franklin Roosevelt. See G. Pascal Zachary, *Endless Frontier: Vannevar Bush, Engineer of the American Century* (Cambridge: MIT Press, 1999). A U.S. Department of Defense study traced the origin of seven hundred key contributions to weapons systems between 1958 and 1966. It found 91 percent to be "technological," 8.7 percent "applied science," and 0.3 percent from "pure" undirected basic research. Ferguson, *Engineering and the Mind's Eye,* 220 n. 18.

32. Sarewitz, *Frontiers of Illusion,* 41–42, 78, 77, 94.

33. Thomas Homer-Dixon, *The Ingenuity Gap* (Toronto: Vintage Canada, 2001), 53 (population), 56 (Fresh Kills landfill site).

34. See Elizabeth V. Spelman, *Repair: The Impulse to Restore in a Fragile World* (Boston: Beacon Press, 2002); and Arnold Pacey, *The Culture of Technology* (Cambridge: MIT Press, 1983), 83, 109.

35. See James Rachels, *Created from Animals: The Moral Implications of Darwinism* (Oxford: Oxford University Press, 1990). I discuss Darwin and Kant on the natural history of morality in "Evil and Enmity," *Common Knowledge* 10 (2004): 185–97.

36. Bruno Latour, "On the Partial Existence of Existing and Nonexisting Objects," in *Biographies of Scientific Objects,* ed. Lorraine Daston (Chicago: University of Chicago Press, 2000), 265.

37. Bruno Latour, "Morality and Technology: The End of the Means," *Theory, Culture & Society* 19 (2002): 258. I also draw from Latour, *Politics of Nature: How to Bring the Sciences into Democracy,* trans. Catherine Porter (Cambridge: Harvard University Press, 2004).

38. Eduardo Torroja, *Philosophy of Structures,* trans. J. J. Polivka and Milos Polivka (Berkeley: University of California Press, 1958), 88. The approximate force of the horizontal thrust in a Roman arch is the live and dead load multiplied by one eighth of the span-to-rise ratio (87).

39. With the pointed arch, coming into use in the twelfth century, especially in the Ile-de-France, "walls became merely enclosures or partitions . . . if need be, they could be constructed after the basic structure of the building was completed; indeed, they could be eliminated entirely." Eugène-Emmanuel Viollet-Le-Duc, *The Foundations of Architecture: Selections from the Dictionnaire Raisonné,* trans. Kenneth D. Whitehead (New York: George Braziller, 1990), 134.

40. O. H. Ammann, "The Bridges of New York," *Journal of the Boston Society of Civil Engineers* 32 (1945): 159.

41. See for instance David Billington, *Tower and Bridge;* J. E. Gordon, *Structures* (London: Penguin, 1978), chap. 16; Alan Holgate, *Aesthetics of Built Form* (Oxford: Oxford University Press, 1992); Ferguson, *Engineering and the Mind's Eye;* Fritz Leonhardt, *Bridges: Aesthetics and Design* (Cambridge: MIT Press, 1984); and Torroja, *Philosophy of Structures,* chap. 17.

42. Gustave Eiffel is cited from Paul Souriau, *The Aesthetics of Movement,* trans. Manon Souriau (Amherst: University of Massachusetts Press, 1983), 100.

43. Quotations from O. H. Ammann, "The Hell Gate Arch Bridge," *Transactions of the American Society of Civil Engineers* 82 (1918): 867, 863; and a remark quoted in Darl Rastorfer, *Six Bridges: The Legacy of Othmar H. Ammann* (New Haven: Yale University Press, 2000), 1.

44. Candela, cited in Billington, *Tower and Bridge,* 218.

45. Quotations in this paragraph from G. F. C. Rogers, *The Nature of Engineering: A Philosophy of Technology* (London: Macmillan, 1983), 65; Billington, *Tower and Bridge,* 265, 142; and Gordon, *Structures,* 199. On the proliferation of choices in advanced technological systems, see also Robert Pool, *Beyond Engineering* (New York: Oxford University Press, 1997), chap. 5.

46. Ammann, "Hell Gate Bridge," 865. Lindenthal was for many years New York City's Commissioner of Bridges. According to a memoir in the American Society of Civil Engineers' *Transactions,* he "never built two bridges alike," "look[ing] on each bridge problem as new and unique, a problem whose proper solution could hardly be the same as that of any prior bridge problem." Cited in Henry Petroski, *Engineers of Dreams: Great Bridge Builders and the Spanning of America* (New York: Knopf, 1995), 193.

47. Ammann, "Present Trends in Structural Design," *Civil Engineering* 10 (1940): 23–24.

48. Torroja, *Philosophy of Structures,* 56; and Pier Luigi Nervi, *Aesthetics and Technology in Building,* trans. Robert Einaudi (Cambridge: Harvard University Press, 1965), 22.

49. Torroja, *Philosophy of Structures,* 18.

50. Billington, *Tower and Bridge,* 216.

51. Pier Luigi Nervi, *Structures* (New York: F. W. Dodge, 1956), 30.

52. Billington, *Tower and Bridge,* 219. Thomas Telford, the greatest bridge designer of his generation, is remembered for a groundbreaking early suspension bridge (1826) over the Menai Straits in Wales, which I mentioned in discussing Stephenson's later Britannia Bridge crossing the same waters.

53. Ammann, "George Washington Bridge," *Transactions of the American Society of Civil Engineers* 97 (1933): 47.

54. Ammann, "Bridges of New York," 149.

55. See David Billington, *Robert Maillart and the Art of Reinforced Concrete* (Cambridge: MIT Press, 1990), 91, 139; and *Robert Maillart: Builder, Designer, and Artist* (Cambridge: Cambridge University Press, 1997). Maillart and Ammann were both students of Wilhelm Ritter at Zürich's Federal Polytechnical Institute. Appropriately designed reinforced concrete structures can be thinner (proportional to span) than eggshell. Torroja, *Philosophy of Structures,* 107.

56. See Robert Maillart, "On the Calculation of Reinforced Concrete," in Max Bill, *Robert Maillart,* 2d ed. (Zürich: Girsberger, 1955); and David Billington, *Robert Maillart's Bridges: The Art of Engineering* (Princeton: Princeton University Press, 1979), 47, 107. Full-scale testing, however obvious, was contrary both to practice and academic theory (Billington, *Maillart, Builder,* 75).

57. Billington, *Maillart, Builder,* 149.

58. The Sydney Harbour Bridge, completed a few months before the Bayonne Bridge, is a spandrel arch resembling Lindenthal's in profile, while its clear span is nearly as great as Ammann's, which exceeds it by a mere 25 feet. It also has the stone piers Ammann designed for his Bayonne Bridge but which were never constructed.

59. Ammann, "Hell Gate Bridge," 871.

60. The Bayonne Bridge was in fact the first significant use of manganese steel. Ammann, "Structural Design," 23. I also draw on Rastorfer, *Six Bridges,* 8, 85; and Billington, *Tower and Bridge,* 138. Technically, only the lower chord, which carries the load, is made of manganese alloy. The top chord, whose contribution is stiffness, is made of silicon steel. Bear in mind that Bayonne Bridge is designed for automobile traffic and a load of 7000 pounds per foot of bridge, whereas Hell Gate, a railway bridge with four lines of track, has a carrying capacity of 75,000 pounds per foot of bridge, a value that has never been exceeded.

61. Ammann, cited in Rastdorfer, *Six Bridges,* 92, 77.

62. Billington, *Tower and Bridge,* 128.

63. Henry B. Seaman and Charles Evan Fowler, commenting on Ammann, "Hell Gate Bridge," 1020, 1012; Carl Condit, *American Building Art* (Oxford: Oxford University Press, 1961), 121.

64. Ammann, "Hell Gate Bridge," 865, 882.

65. Henry H. Quimby, commenting on Ammann, "Hell Gate Bridge," 1018; and Ammann, "Hell Gate Bridge," 870. Torroja appreciates the need to attend to the visual qualities of a structure: "The beauty

of constructional work is known through sight. . . . Hence more important than its actual geometrical reality, it is the visual aspect of the work that matters." *Philosophy of Structures,* 285.

66. Nervi, *Aesthetics and Technology,* 5. On the problem of ceilings in medieval architecture, see also Arnold Pacey, *The Maze of Ingenuity* (Cambridge: MIT Press, 1974), 28–32.

67. Gordon, *Structures,* 184.

68. Ammann, "Hell Gate Bridge," 870, 882–83.

69. Ibid., 1036; Moisseiff's comment appears on 1007.

70. Ammann, "George Washington Bridge," 51.

71. Rudolf Arnheim, *Toward a Psychology of Art* (Berkeley: University of California Press, 1966), 322.

72. Ammann, "George Washington Bridge," 51.

73. Ammann (1958), cited in Rastdorfer, *Six Bridges,* 39.

74. M. P. Burke, Jr., "Aesthetically Notorious Bridges," *Civil Engineering* 126 (1998): 39–47. The aesthetically notorious bridges are: Lansdowne Bridge, Indus River, Pakistan, 1869; Williamsburg Bridge, East River, New York, 1904; Queensboro Bridge, East River, New York, 1909; Hungerford Bridge, Thames, London, 1864; and Tower Bridge, Thames, London, 1894. Lindenthal was inadvertently associated with both New York bridges, taking over as Commissioner of Bridges after they were under construction. He tried to modify the designs, but was unsuccessful, and had his name removed from a plaque on the Williamsburg Bridge. Sometimes the public warms to a bridge the professionals dislike, like London's Tower Bridge. The public seems to love precisely the qualities that make professionals cringe. But usually (and in every other case here) professional and nonprofessional opinion concur.

75. Ibid., 40.

76. Ibid., 43.

77. Unnamed author, writing in *The Engineer;* cited ibid., 40.

78. Ibid., 45.

79. Hart Crane, "Proem: To Brooklyn Bridge," *The Bridge* (1933) (New York: Liveright, 1970), 2.

80. Lienhard, *Engines of Our Ingenuity,* 189–90.

81. L. T. C. Rolt, *Landscape with Machines* (London: Longman, 1971), 226. Following Perry Miller, American historian Leo Marx writes of the "technological sublime," a theme developed in the work of David Nye. See Leo Marx, *The Machine in the Garden: Technology and the Pastoral Ideal in America* (Oxford: Oxford University Press, 1964); and David Nye, *American Technological Sublime* (Cambridge: MIT Press, 1996). The idea, in brief, is that during a moment of the late Romantic period (mid- to late nineteenth century), some mainly American authors began to write of the sublime appeal of great works of technology, such as a locomotive, bridge, or factory. I haven't spoken much about "the sublime," because I don't think it's a useful distinction to make any more. As I see it, what tradition describes as the sublime is one face of the rich, historically developing repertory of beauty, and not something to carefully distinguish from the experience of beauty, as it is in the aesthetic psychology of Burke or Kant.

## 5. Art

1. See Marga Bijvoet, "How Intimate Can Art and Technology Be? A Survey of the Art and Technology Movement," in *Culture, Technology, and Creativity,* ed. Philip Hayward (London: John Libby, 1990). In 1917, Russian Constructivist artist Vladimir Tatlin called for "art going out into technology." Margot Lovejoy, *Digital Currents: Art in the Electronic Age* (New York: Routledge, 2004), 38.

2. Philip Ball, *Bright Earth: Art and the Invention of Color* (Chicago: University of Chicago Press, 2001), 223. I also draw on 208, 215, 334.

3. I draw from K. Aslihan Yener, *The Domestication of Metals* (Leiden: Brill, 2000), 12, 15, 17, 31–33, 126.

4. Cyril Stanley Smith, *A Search for Structure* (Cambridge: MIT Press, 1981), 195.

5. Smith, *Search for Structure,* 113; Ball, *Bright Earth,* 56, 62.

6. Michael C. Corballis, *From Hand to Mouth: The Origins of Language* (Princeton: Princeton University Press, 2002), 137.

7. See Armand Mattalart, *The Invention of Communication,* trans. Susan Emanuel (Minneapolis: University of Minnesota Press, 1996); and William J. Mitchell, *City of Bits* (Cambridge: MIT Press, 1995).

8. J. R. Beniger, *The Control Revolution: Technological and Economic Origins of the Information Society* (Cambridge: Harvard University Press, 1986), 25, 32, 426.

9. Dana Birnbaum, "The Individual Voice as a Political Voice: Critiquing and Challenging the Authority of Media," in *Women, Art, and Technology,* ed. Judy Malloy (Cambridge: MIT Press, 2003), 139–40.

10. Joanna Overing, "Aesthetics as a Cross-Cultural Category," in *Key Debates in Anthropology,* ed. Tim Ingold (London: Routledge, 1996), 260. For an even harder line against aesthetics in anthropology see Alfred Gell, "The Technology of Enchantment and the Enchantment of Technology," in *Anthropology, Art, and Aesthetics,* ed. Jeremy Coote and Anthony Shelton (Oxford: Clarendon Press, 1992). That "art" and "aesthetic" are social constructs of the modern West without application beyond its boundaries is also the argument of Pierre Bourdieu, *Distinction: A Social Critique of the Judgment of Taste,* trans. R. Nice (London: Routledge & Kegan Paul, 1984). On the history of anthropological struggle with the phenomena of aesthetics, see Wilfred van Damme, *Beauty in Context: Towards an Anthropological Approach to Aesthetics* (Leiden: E. J. Brill, 1996).

11. Richard L. Anderson, *Calliope's Sisters: A Comparative Study of Philosophies of Art,* 2d ed. (Upper Saddle River, N.J.: Pearson Prentice Hall, 2004), 262, 323–26; and Elizabeth Prette-John, *Beauty and Art, 1750–2000* (Oxford: Oxford University Press, 2005).

12. Stephen Davies, "Essential Distinctions for Art Theorists," in *Art and Essence,* ed. Stephen Davies and Ananta C. Sukla (Westport: Praeger, 2003), 14. See also Stephen Davies, *The Definition of Art* (Ithaca: Cornell University Press, 1991).

13. Jacques Maquet, *The Aesthetic Experience: An Anthropologist Looks at Art* (New Haven: Yale University Press, 1986), 149.

14. Maquet, *Aesthetic Experience,* 58, 60, 182; and Dennis Dutton, "Aesthetic Universals," in *The Routledge Companion to Aesthetics,* ed. Berys Gaut and Dominic McIvers Lopes (London: Routledge, 2001). Empirical universality doesn't imply a naturally selected adaptation. See Daniel C. Dennett, *Darwin's Dangerous Idea* (New York: Simon & Schuster, 1995), 486–87. Arts like drawing, carving, and painting were probably invented many times, just as arts like agriculture, urbanism, writing, and mathematics were.

15. Clifford Geertz, "Art as a Cultural System," in *Local Knowledge,* 3d ed. (New York: Basic Books, 2000), 119–20. Similarly, "the peculiar power of works of art does not reside in the objects *as such* . . . [rather,] in the *symbolic* processes they provoke in the beholder." Gell, "Technology of Enchantment," 48.

16. See Patrick Maynard, *Drawing Distinctions: The Varieties of Graphic Expression* (Ithaca: Cornell University Press, 2005), 120–25, 211.

17. See Wendy Steiner, *Venus in Exile: The Rejection of Beauty in Twentieth-Century Art* (Chicago: University of Chicago Press, 2001); and Prette-John, *Beauty and Art.*

18. Arthur C. Danto, *The Abuse of Beauty* (Chicago: Open Court, 2003), 48, 49, 53.

19. Thierry de Duve, *Kant after Duchamp* (Cambridge: MIT Press, 1996), 91, 269.

20. Anthony Julius, *Transgressions: The Offences of Art* (Chicago: University of Chicago Press, 2002), 204. There is a photograph of the horse/artwork in Nigel Warburton, *The Art Question* (London: Routledge, 2003), 1. In a 1961 performance in Milan, Piero Manzoni turned living bodies into "authentic works of art" by signing them. Marvin Carlson, *Performance,* 2d ed. (New York: Routledge, 2004), 105.

21. See George Dickie, *Art and the Aesthetic: An Institutional Analysis* (Ithaca: Cornell University Press, 1974); Arthur C. Danto, "The Artworld," *Journal of Philosophy* 61 (1964): 571–84; and for criticism, Paul Crowther, *Defining Art, Creating the Canon: Artistic Value in an Era of Doubt* (Oxford: Clarendon Press, 2007), chap. 1.

22. Sol Le Witt, "Paragraphs on Conceptual Art," *ArtForum* 5 (10) (1967): 79–83; and Duchamp, cited in Lovejoy, *Digital Currents,* 45–46.

23. Duve, *Kant after Duchamp,* 278.

24. Nihilism is a concept most of us know from Nietzsche. Older uses of the word, going back to Ivan Turgenev, are largely forgotten and irrelevant. For Nietzsche's idea, which I only partially follow here, see Maurice Blanchot, "The Limits of Experience: Nihilism," in *The New Nietzsche,* ed. David B. Allison (New York: Delta, 1977); and Randall Havas, *Nietzsche's Genealogy: Nihilism and the Will to Knowledge* (Ithaca: Cornell University Press, 1995). For a different view, see Gianni Vattimo, *Nihilism and Emancipation,* ed. Santiago Zabala, trans. William McCuaig (New York: Columbia University Press, 2004).

25. Duchamp is cited from Marcel Duchamp, *Salt Seller: The Writings of Marcel Duchamp,* ed. Michel

Sanouillet and Elmer Peterson (New York: Oxford University Press, 1973), 141; and in Duve, *Kant after Duchamp,* 175, 166. On motives of retaliation, irony, revenge, nostalgia, jealousy, and impotence in Duchamp, see ibid., 167–70. On his "helplessness in the face of ordinary life drawing," see James Elkins, *Master Narratives and Their Discontents* (London: Routledge, 2005), 134–35.

26. Donald Kuspit, *The End of Art* (Cambridge: Cambridge University Press, 2004), 45, 62. *Post-art* is a concept from conceptual artist Allan Kaprow, *Essays on the Blurring of Art and Life* (Berkeley: University of California Press, 1993).

27. "Art, considered in its highest vocation, is and remains for us a thing of the past. It has lost for us genuine truth and life." G. W. F. Hegel, *Aesthetics: Lectures on Fine Art,* vol. 1, trans. T. M. Knox (Oxford: Clarendon Press, 1975), 11.

28. Duchamp repeatedly described his art as "nominalism"; see Duve, *Kant after Duchamp,* 165–66.

29. Charles Darwin, *The Origin of Species and The Descent of Man* (New York: Modern Library, 1936), 371; and *Darwin's Notebooks on Transmutation of Species,* ed. Gavin de Beer (London: Bulletin of the British Museum, 1960), vol. 2, no. 3, p. 88.

30. My view is different from the so-called historical definition of art by Jerrold Levinson, "Defining Art Historically," *British Journal of Aesthetics* 19 (1979): 232–50. He makes Nietzsche's point that a concept like art has no content beyond what art has been, but seeks the "historical" unity of art in the intention (and consciousness) of individual artists. For something to be art is for it to be intentionally related to the art that precedes it. In my view, the "unity" is retrospective rather than intentional, modeled on the unity of species in an evolving genus.

31. See James Elkins, *Stories of Art* (New York: Routledge, 2002).

32. "Dance and body-painting constituted the earliest art media, long before the production of representational imagery on inanimate surfaces." Camilla Powers, "Beauty Magic: The Origins of Art," in *The Evolution of Culture,* ed. Robin Dunbar, Chris Knight, and Camilla Powers (New Brunswick: Rutgers University Press, 1999), 108–9.

33. *Fountain* wasn't actually exhibited at the show to which it was pseudonymously submitted (Duchamp was on the selection committee). It was rejected by the supposedly nonrejecting jury (Society of Independent Artists) on a technicality—the entry card was improperly completed. Now it has disappeared. All that exists are replicas (Sidney Janis, 1950; Ulf Linde, 1963; Arturo Schwarz, 1964), and a Stieglitz photograph (1917). Duve, *Kant after Duchamp,* 95–96, 99.

34. David Pye, *The Nature and Art of Workmanship,* rev. ed. (Bethel, Conn: Cambium Press, 1995), 63.

35. Ibid., 55, 62, 127–28.

36. E. H. Gombrich, *The Sense of Order* (Oxford: Phaidon Press, 1979), 173. Hannah Arendt, *The Human Condition,* 2d ed. (Chicago: University of Chicago Press, 1998). Martin Heidegger, "The Origin of the Work of Art," in *Off the Beaten Track,* ed. and trans. Julian Young and Kenneth Haynes (Cambridge: Cambridge University Press, 2002). For a version of this thought free of Heidegger's ontology and Arendt's Hellenocentrism, one may consider the work of Confucian philosopher Xunzi. See, for instance, *Xunzi: Basic Writings,* trans. Burton Watson (New York: Columbia University Press, 2003).

37. Rodin, cited in Moshe Barasch, *Modern Theories of Art,* vol. 2: *Impressionism to Kandinsky* (New York: New York University Press, 1998), 76.

38. See Penny Sparke, *Introduction to Design and Culture,* 2d ed. (London: Routledge, 2004); and Virginia Postrel, *The Substance of Style* (New York: HarperCollins, 2003).

39. Bruno Latour, "Morality and Technology: The End of the Means," *Theory, Culture & Society* 19 (2002): 258.

40. Homer, *Iliad* 18.546–49; cited and discussed in Bernard Bosanquet, *A History of Aesthetic,* 2d ed. (London: George Allen and Unwin, 1904), 12; and *Three Lectures on Aesthetic,* ed. Ralph Ross (Indianapolis: Bobbs-Merrill, 1963), 28–29. My reading of the wonder is not Bosanquet's, as I explain in "The Ubiquitous Artifact," *New Literary History* 35 (2004): 259–71. On *wonder* (*thauma*) and artifactual presence in antiquity see Robert Hahn, *Anaximander and the Architects* (Albany: State University of New York Press, 2001). A Mesopotamian word translated as *wonder* was also the usual sobriquet for seeing the ziggurats of Ur, as well as a term applied to early Mesopotamia sculpture. The word is apparently composed from a verb signifying intense visual engagement. Irene J. Winter, "Defining 'Aesthetics' for Non-Western Studies," in *Art History, Aesthetics, Visual Studies,* ed. Michael Ann Holly and Keith Moxey (Williamstown, Mass.: Clark Art Institute, 2002), 12–13.

41 . The most salient visual aspect of drawings is that they *look* like drawings," "their lines *look* drawn." Maynard, *Drawing Distinctions,* 106, 223.

42. Rudolf Arnheim, *Visual Thinking* (Berkeley: University of California Press, 1969), 3. John Dewey makes a similar point at length in *Art as Experience* (New York: G. P. Putnam's Sons, 1934).

43. Kimon Nicolaïdes, *The Natural Way to Draw* (Boston: Houghton Mifflin, 1941), 5.

44. David Rosand, *Drawing Acts: Studies in Graphic Expression and Representation* (Cambridge: Cambridge University Press, 2002), 105, 97. Also, Rudolf Arnheim, *Art and Visual Perception,* rev. ed. (Berkeley: University of California Press, 1974), 206.

45. Maynard, *Drawing Distinctions,* 193; also Karl Aschenbrenner, *The Concept of Coherence in Art* (Dordrecht: Reidel, 1985), 7.

46. There might be social ingenuity. On the distinction between social and technical ingenuity, see Thomas Homer-Dixon, *The Ingenuity Gap* (Toronto: Vintage Canada, 2001), 22. He defines "ingenuity" rather positivistically as "sets of instructions that tell us how to arrange the constituent parts of our social and physical worlds in ways that help us achieve our goals" (21).

47. On innovation (including the clothes button), see Lynn White, Jr., "The Act of Invention," in *Machina Ex Deo: Essays in the Dynamism of Western Culture* (Cambridge: MIT Press, 1968), 130. The first functional button is from central Germany circa 1230. Lynn White, Jr., *Medieval Technology and Social Change* (Oxford: Oxford University Press, 1962), 273.

## In Conclusion

1. "Bipedalism is the key to understanding human brain evolution." Dean Falk, *Braindance: New Discoveries about Human Brain Evolution* (New York: Henry Holt, 1992), 76. A necessary condition only—the evolution of bipedal walking did not by itself initiate encephalization. Steven Stanley, *Children of the Ice Age* (New York: W. H. Freeman, 1998), 52. Describing technology as "analogous to maternal protection," Jonathan Kingdon says, "The ultimate legacy of bipedalism and emancipated hands is that we have prolonged childhood and created an all-embracing technological parent." *Lowly Origin: Where, When, and Why Our Ancestors First Stood Up* (Princeton: Princeton University Press, 2003), 292.

2. On technological complexity and its implications, see Thomas Homer-Dixon, *The Ingenuity Gap* (Toronto: Vintage Canada, 2001); and Robert Pool, *Beyond Engineering* (New York: Oxford University Press, 1997), chap. 4. It is a fantasy congruent with the rationalism of our time that we think technological catastrophes can be planned for and managed, including nuclear accidents, thermonuclear war, or just an oil tanker breaking up at sea. "The fantasy is that . . . the crucial contingencies are known and have been prepared for." Lee Clark, *Mission Improbable: Using Fantasy Documents to Tame Disaster* (Chicago: University of Chicago Press, 1999), 30. Such plans are, as Clark calls them, fantasy documents, meaning rhetorical symbols of administrative rationality offering fatuous reassurance that everything is under control. For example, the U.S. Post Office plan for delivering mail after a thermonuclear strike assumes employees show up for work with no casualties, despite all three locations for central command (present and two alternates) lying in plan-designated high strike areas (ibid., 31–32).

3. Culture as an adaptation to unpredictable environments is the argument of William H. Calvin, *A Brain for All Seasons: Human Evolution and Abrupt Climate Change* (Chicago: University of Chicago Press, 2002); and Peter J. Richerson and Robert Boyd, *Not by Genes Alone: How Culture Transformed Human Evolution* (Chicago: University of Chicago Press, 2005). On the environmental conditions of hominid evolution, see Richard Potts, *Humanity's Descent: The Consequences of Ecological Instability* (New York: Avon, 1996); William J. Burroughs, *Climate Change in Prehistory* (Cambridge: Cambridge University Press, 2005); and Pamela R. Willoughby, *The Evolution of Modern Humans in Africa* (Lanham: AltaMira Press, 2007), chap. 3.

4. Calvin, *Brain for All Seasons,* 185; also 91, 190, 201; and Richerson and Boyd, *Not by Genes Alone,* 7, 116, 146.

5. The relation of uncertainty and ethics is a theme of John Ralston Saul, *On Equilibrium* (Toronto: Penguin Canada, 2001).

6. On the limitations of "machine-centered engineering," as well as evidence of new attitudes in en-

gineering toward the waste products of engineered systems, see Pool, *Beyond Engineering,* chap. 9, and 287–93.

7. Bruno Latour, *We Have Never Been Modern,* trans. Catherine Porter (Cambridge: Harvard University Press, 1993).

8. Ibid., 145; and Latour, *Politics of Nature: How to Bring the Sciences into Democracy,* trans. Catherine Porter (Cambridge: Harvard University Press, 2004).

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